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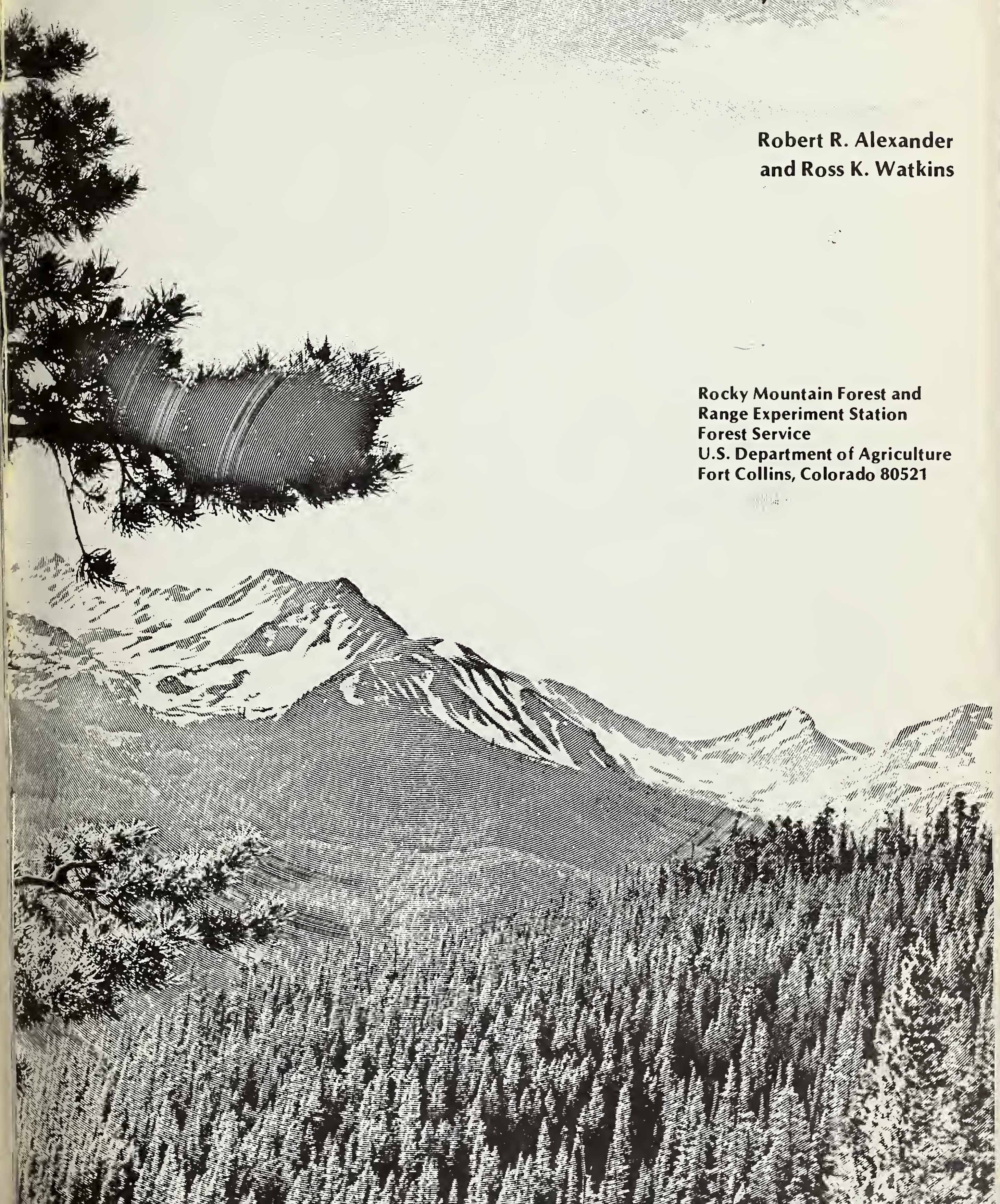
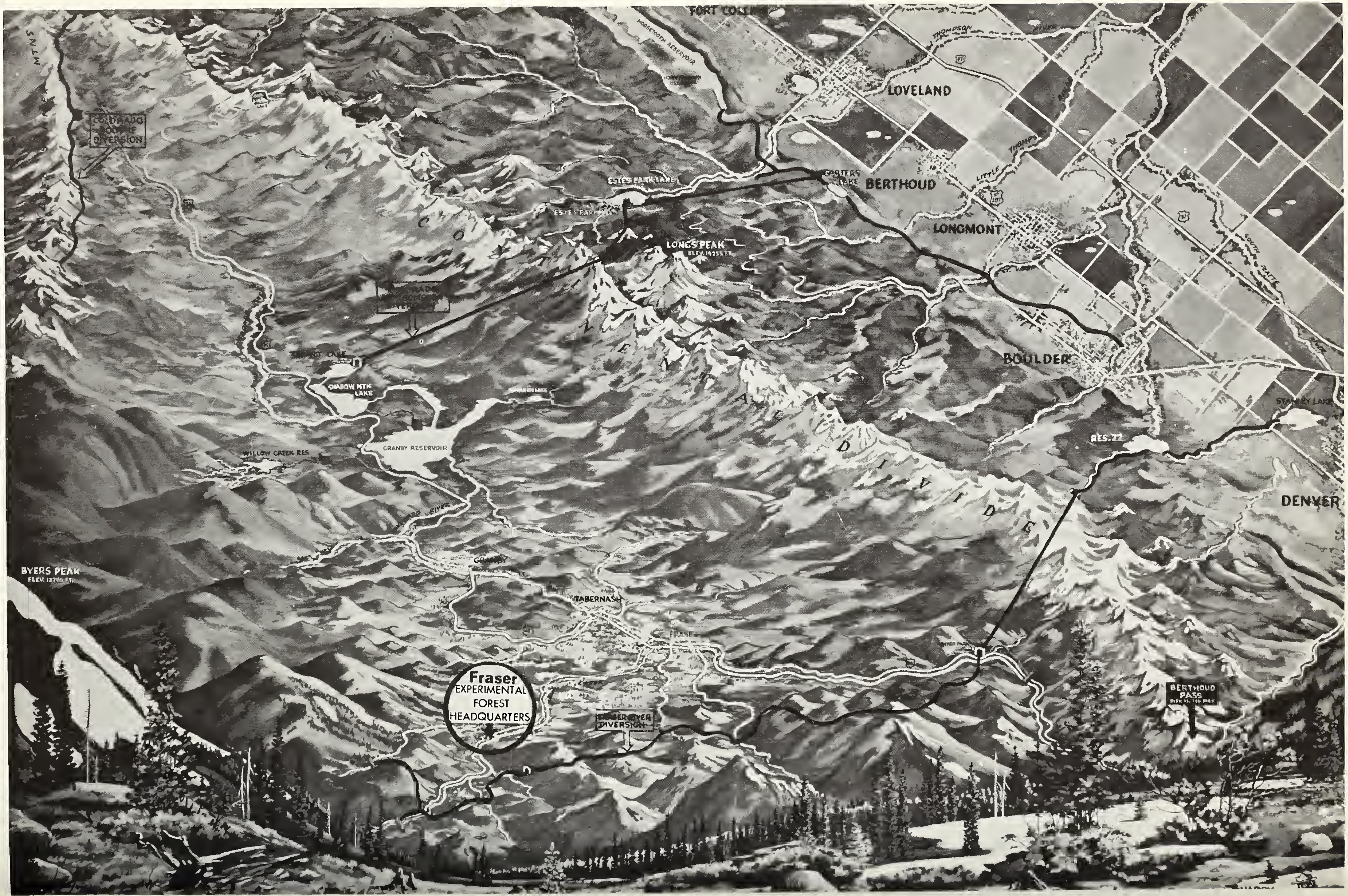
September 1977

The Fraser Experimental Forest, Colorado

Robert R. Alexander
and Ross K. Watkins

Rocky Mountain Forest and
Range Experiment Station
Forest Service
U.S. Department of Agriculture
Fort Collins, Colorado 80521





FORT COLLINS
HORSETOOTH RESERVOIR
LOVELAND
BERTHOUD
LONGMONT
BOULDER
DENVER
CARTERS LAKE
ESTES PARK LAKE
LONGS PEAK
CONTINENTAL DIVIDE
COLORADO RIVER DIVERSION
SHADOW MTN LAKE
GRANBY RESERVOIR
WILLOW CREEK RES
BYERS PEAK
TABERNASH
RES. 22
Fraser
EXPERIMENTAL
FOREST
HEADQUARTERS
FRASER RIVER DIVERSION
BERTHOUD PASS
MTNS

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The Fraser Experimental Forest, Colorado

Robert R. Alexander, and Ross K. Watkins[1]

[1]*Alexander is Chief Silviculturist, and Watkins is Forestry Research Technician at the Rocky Mountain Forest and Range Experiment Station, with central headquarters maintained at Fort Collins in cooperation with Colorado State University.*

Contents

THE FRASER EXPERIMENTAL FOREST, COLORADO

Robert R. Alexander, and Ross K. Watkins

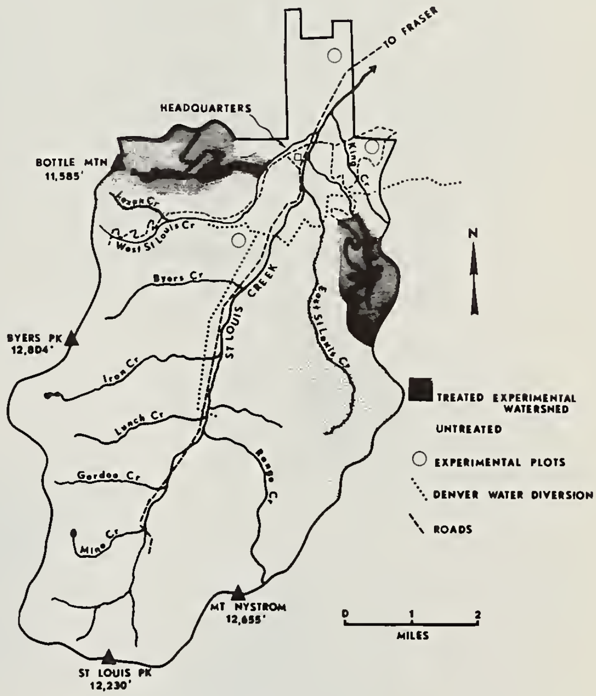
The Fraser Experimental Forest was established in 1937 in the heart of the central Rocky Mountains. This 36-square-mile outdoor research laboratory maintained by the Rocky Mountain Forest and Range Experiment Station is located 50 air miles west of Denver, Colo. The location is well suited to the study of timber, water and wildlife management, and their integration in high elevation subalpine coniferous forests.

In the West, water is vital to life and development. St. Louis Creek, the main drainage on the Fraser Experimental Forest, is typical of headwater streams that are the source of 85% of the annual yield of about 20 million acre feet of water from the Colorado Rockies.

The relationship between water sources in high elevation forests, extensive transmountain diversions, and domestic, industrial and agricultural users is shown in a schematic view of the Fraser Experimental Forest and its surrounding country. The Colorado-Big Thompson transmountain diversion taps the headwaters of the Colorado River and brings water through the 13-mile-long Alva Adams Tunnel to users on the east side of the Continental Divide. The Fraser River transmountain diversion, constructed by the City of Denver to bring water from St. Louis and Vasquez Creeks, crosses the Continental Divide through the pioneer bore of the 6-mile-long Moffat Tunnel.

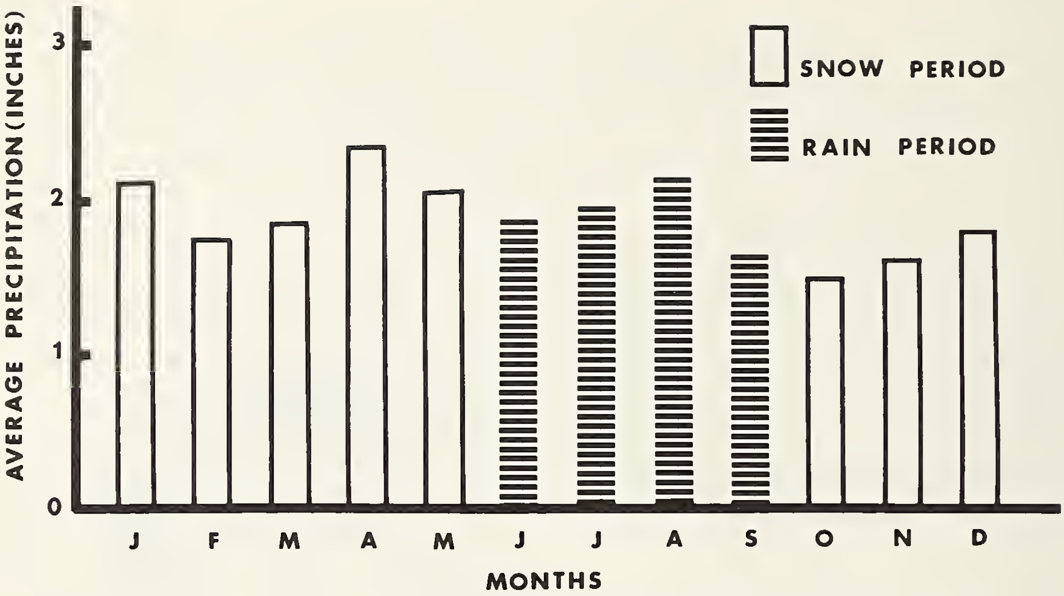
THE FOREST

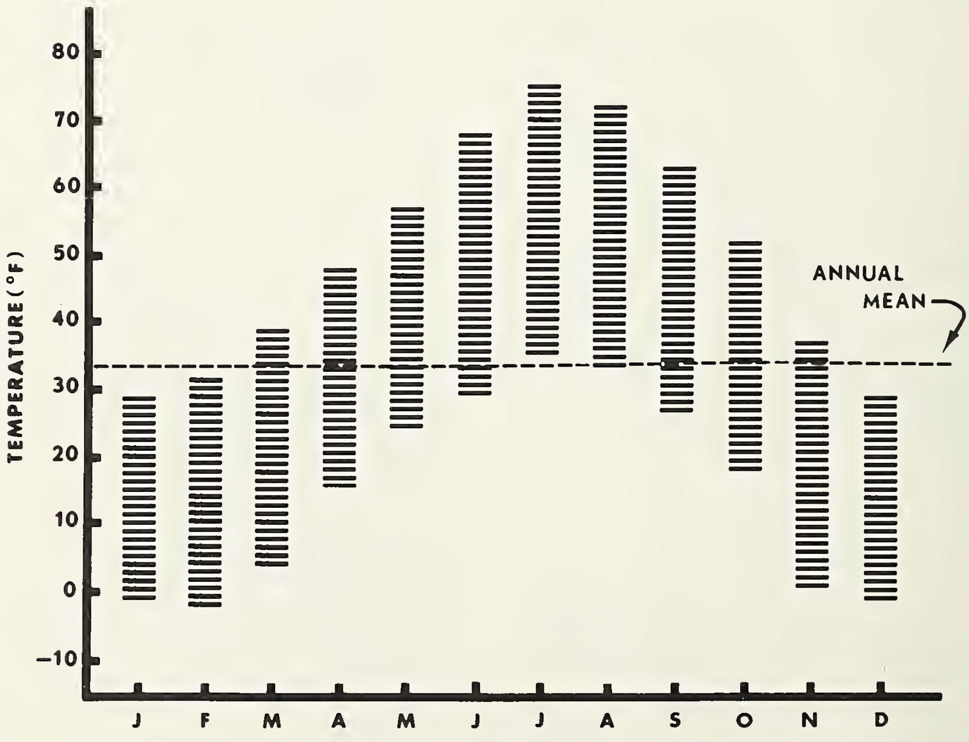
Elevation of the Experimental Forest ranges from 8,800 feet at the main entrance along the road from the town of Fraser, to 12,804 feet at the summit of Byers Peak. About three-fourths of the Forest lies above 10,000 feet, and about one-third is above timberline.



Climate

Climate is cool and humid with long, cold winters and short, cool summers. Average yearly temperature at Forest headquarters (9,000 feet elevation) is 33°F., and frost can occur any month of the year. Mean monthly temperature for January is 14°F, for July 55°F, with an observed range of about −40°F to 90°F. Annual precipitation measured at the headquarters area varies from about 17 to 28 inches, with an average of nearly 23 inches. Precipitation over the entire Experimental Forest averages about 28 to 30 inches with nearly two-thirds falling as snow from October through May.


AVERAGE PRECIPITATION (INCHES)
0
1
2
3
SNOW PERIOD
RAIN PERIOD
J F M A M J J A S O N D
MONTHS

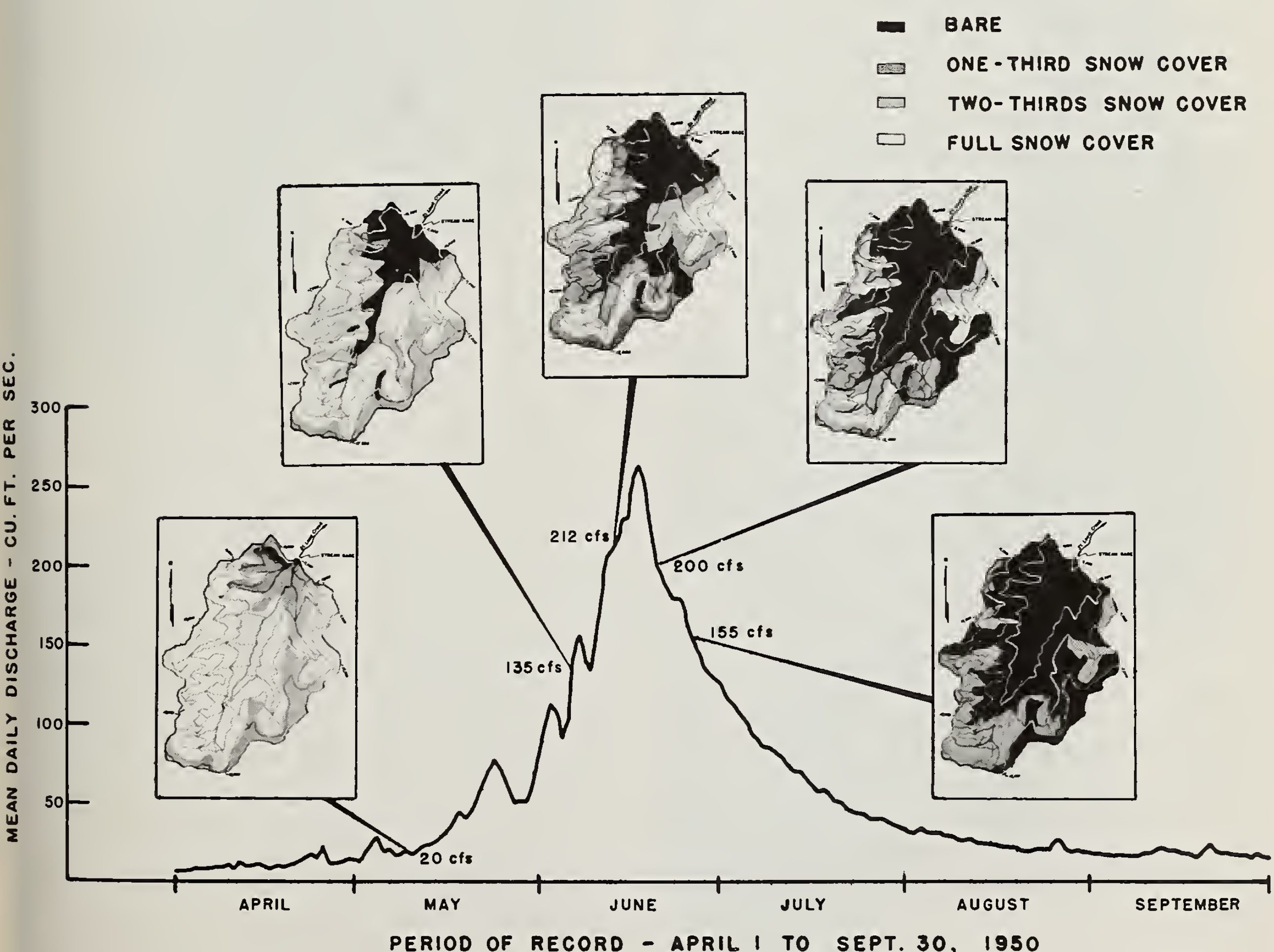

TEMPERATURE (°F)
80
70
60
50
40
30
20
10
0
−10
ANNUAL MEAN
J F M A M J J A S O N D
MONTHS

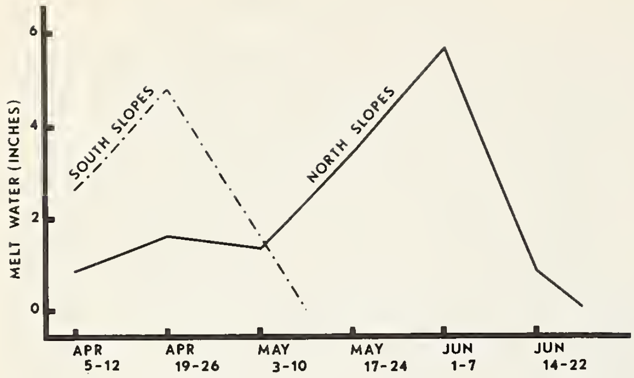
Water Yield

Snowfall is the key to water yield. On the Experimental Forest, the first snow is deposited in late fall, and the pack gradually accumulates to its maximum depth in early spring. Long, cold winters keep temperatures within the snowpack well below freezing until late March or April. Peak seasonal snow accumulation averages about 15 inches water equivalent, and during melt season, the depleting snowpack is augmented by 5 inches or more of additional precipitation. Rainfall during summer and early fall averages 8 to 10 inches. Of the total 28 to 30 inch input, about 12 to 15 inches becomes streamflow. Streams begin to rise from minimum flows in April, reaching peak levels in June. Streamflow then rapidly recedes, nearing baseline flows again in late summer.

Snow Cover Disappearance

The entire Forest is covered with snow by the end of winter. As spring advances, snow disappears progressively from lower to higher elevations. Snow melts and disappears from south slopes first. When 50% of the snow has disappeared, spring streamflow peaks on the main drainage; when 80% of the snow is gone, streamflow is declining. Temperature, humidity, and wind also influence the daily rate of snowmelt which, in turn, governs streamflow. Continuous records of these factors have been useful in calculating rates of streamflow on the St. Louis Creek drainage, and in forecasting daily streamflow.





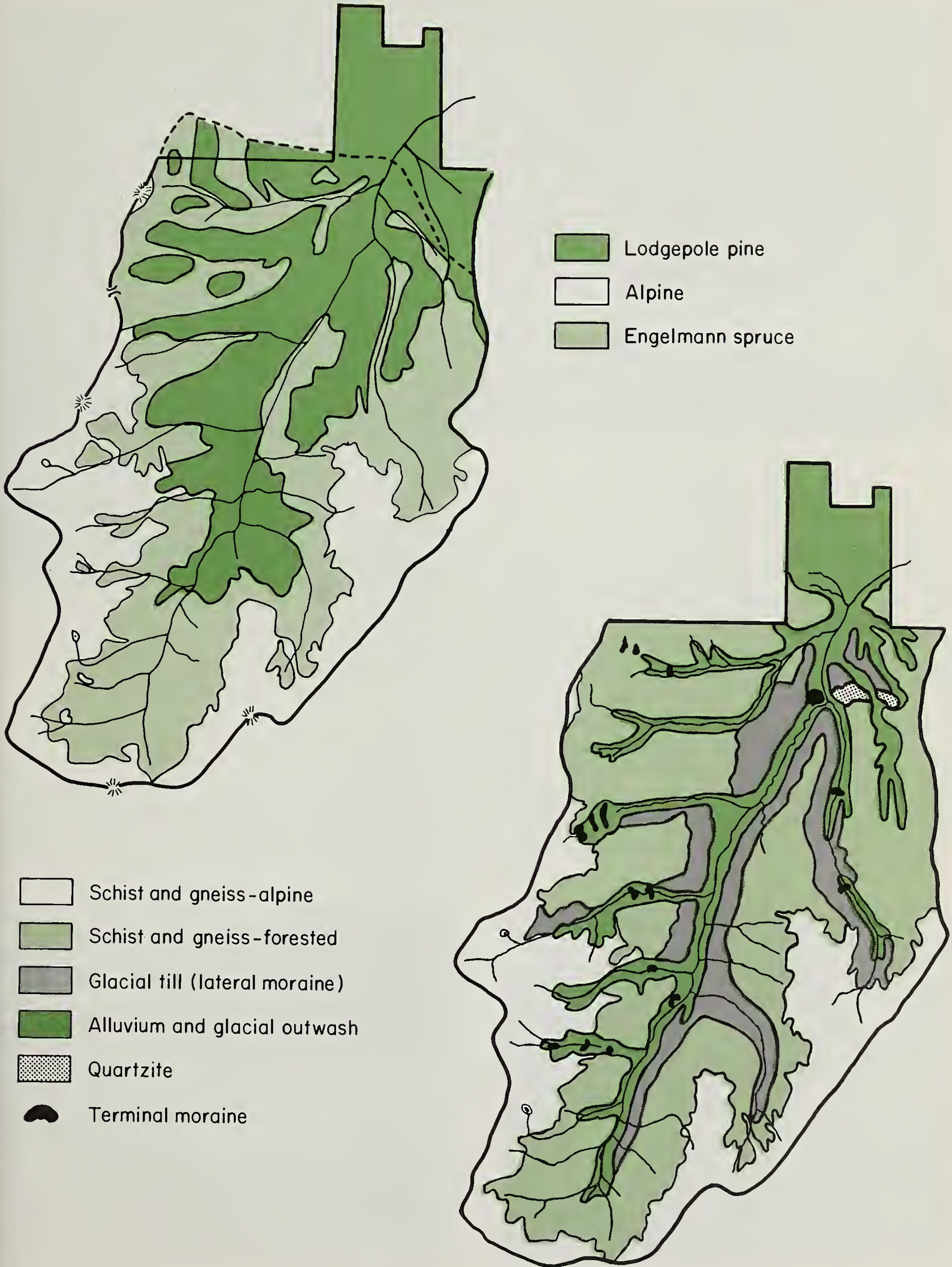
Geology, Landforms and Soils

Topography of the Experimental Forest is typical of the Southern Rocky Mountain Province. The west side of the Forest is characterized by rugged mountains and narrow, steep-sided valleys filled with alluvium and glacial outwash. South and east sides of the Forest are remnants of an old peneplain, dissected by mountain glaciers and characterized by long, gentle, relatively uniform slopes. The north side is a nearly level, broad valley dissected by St. Louis Creek and surrounded by rolling hills.

Parent material of soils on the Forest generally is derived from gneiss and schist rocks. Occasionally, there are small outcroppings of granitic rock, which weathers more slowly than schists. Typical soils from schistic and granitic rock contain angular gravel and stone, with very little silt and clay. They are very permeable and capable of storing considerable amounts of water during snowmelt. At high elevations, especially on the west side of the Forest, soils have developed in material weathered from sandstones. These soils are shallow, have large amounts of stone, and have fine sand or sand textures. Alluvial soils occur along main streams, with parent material a mixture of glacial till, glacial outwash and recent valley fill. Bogs originating from seeps or springs that emerge on slopes are scattered throughout the Forest.

Vegetation

Native vegetation is typical of the subalpine forest zone of the central Rocky Mountains. Engelmann spruce and subalpine fir are predominant trees at higher elevations, on north slopes, and along streams; lodgepole pine is the predominant tree at lower elevations and on drier upper slopes. In virgin stands, trees range from 200 to 400 years old. Second-growth lodgepole pine on the north end of the Forest originated after fires, and is about 60 years old. Scattered patches of aspen occur in areas opened up by logging or fire. Occasionally, a large, old (450 to 500 years) Douglas-fir can be found. The forest floor generally is covered with a layer of duff and litter and often a dense mat of whortleberry. Little herbaceous vegetation is present except along streams, and in openings resulting from disturbance. Barren rocks intermix with alpine tundra, meadows and bogs above timberline.


Lodgepole pine
Alpine
Engelmann spruce
Schist and gneiss-alpine
Schist and gneiss-forested
Glacial till (lateral moraine)
Alluvium and glacial outwash
Quartzite
Terminal moraine

Wildlife

Many kinds of wildlife live on the Forest, but no one species is abundant. Trout occur in some streams, beaver ponds, and lakes. Elk, deer, black bear, and mountain lion are the Forest's big game animals. Elk are found in alpine grasslands and high cirque basins in summer, but do not winter in any part of the Forest. Mule deer are more common than elk. In summer, they graze in timbered areas and openings intermixed with timber. In winter, they move to lower areas off the Forest. Black bears are shy and rarely seen. Mountain lions are only occasional visitors. Small, fur-bearing mammals include marten, weasel, mink, badger, muskrat, red fox, coyote, bobcat, and beaver along some watercourses. Snowshoe hares, pine squirrels, porcupines, marmots, chipmunks, ground squirrels, mice, gophers, shrews, and voles also are present. Numerous game and nongame birds occur on the Forest. Some are residents, others are seasonal, and still others are migratory.

Recreation

The Forest provides a variety of recreational opportunities, with two developed campgrounds, 20 miles of specified roads, and many

trails. In summer, users camp, hike, fish, backpack, and view and photograph scenery. In fall, hunters seek blue grouse, elk, and deer. Snowmobiling and ski-touring are popular in winter.

RESEARCH PROGRAM

The research program at the Fraser Experimental Forest is concerned with regenerating new forest stands, increasing growth and yield of trees, increasing water supplies and maintaining water quality, improving wildlife habitat for game and nongame animals, and determining the integrated effects of timber harvesting on these resources. Specifically, research objectives are:

1. Understanding how trees grow, reproduce and interact; how the hydrologic system operates on headwater streams, and what the food and cover requirements of wildlife are.
2. Learning how natural forest cover influences the tree, water and wildlife systems.
3. Observing how management through harvesting timber changes the influence of the forest on these systems; and
4. Devising timber harvesting systems to achieve the desired changes in forest cover that will provide the best mix of timber, water and wildlife benefits.

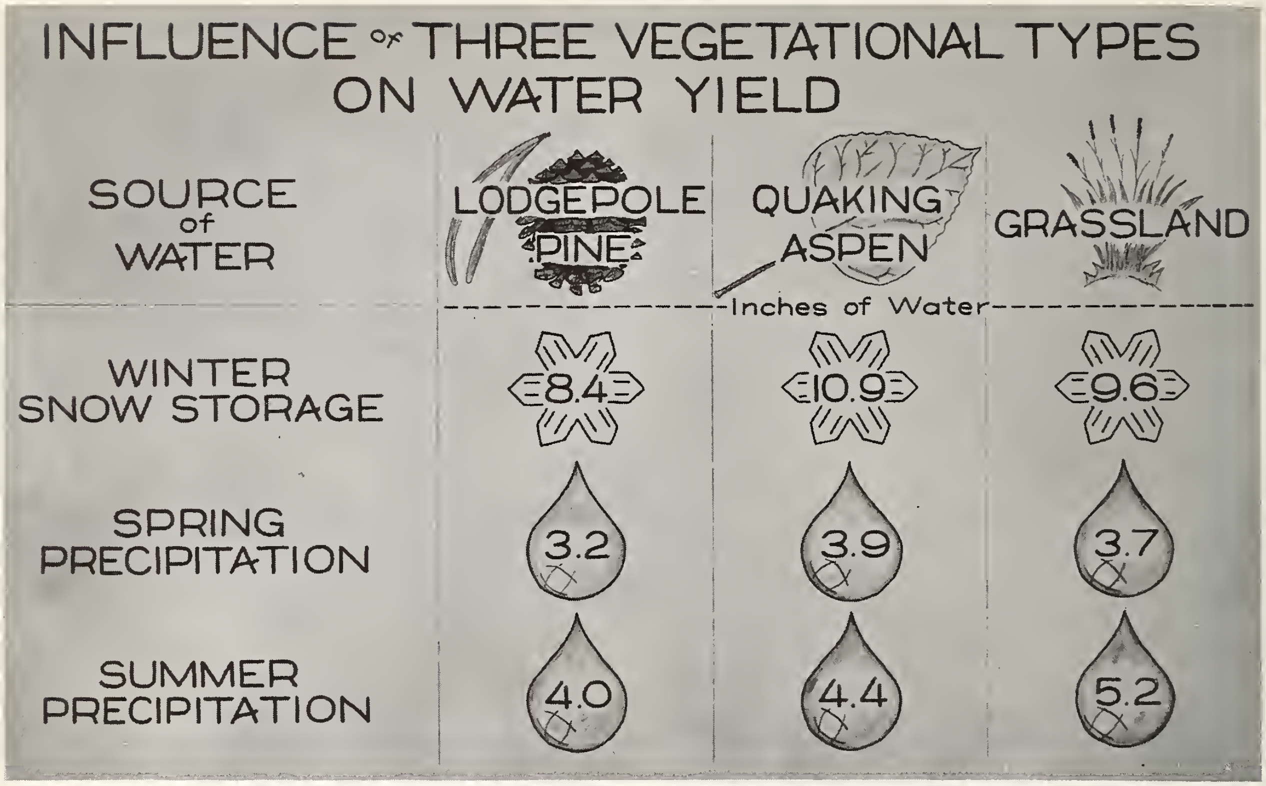
RESEARCH HIGHLIGHTS

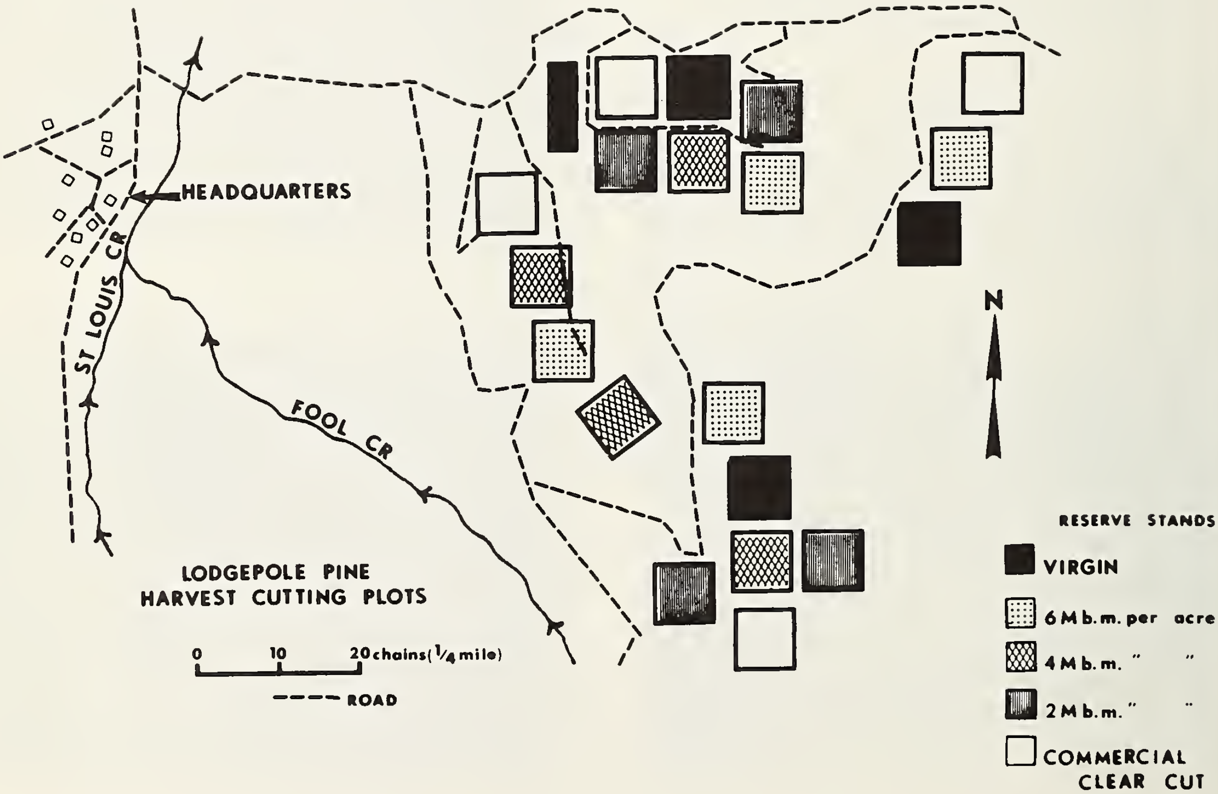
Early studies included observations in natural plant communities or environments to determine their effects on snow accumulation. Results showed more precipitation reached the ground under aspen and in grasslands, than under dense lodgepole pine stands. These studies provided clues to the effect on water yield when forest stands were harvested for timber or thinned to improve growth.

Plot studies of harvest cuttings and thinnings followed. Their purpose was to determine how different methods and intensities of tree removal affected the snowpack and tree reproduction, growth, and mortality. A third research phase applied a timber harvesting system to an entire watershed to measure its effects on (1) streamflow and snow accumulation and melt; (2) sedimentation; (3) tree regeneration and mortality; and (4) big game use, forage availability and preference. This included basic hydrologic studies aimed at measuring water loss from both vegetation and the overwinter snowpack. The present phase involves pilot testing of timber, water, and wildlife systems and their interactions in relation to timber harvesting on other watersheds.

Harvest Cutting in Lodgepole Pine

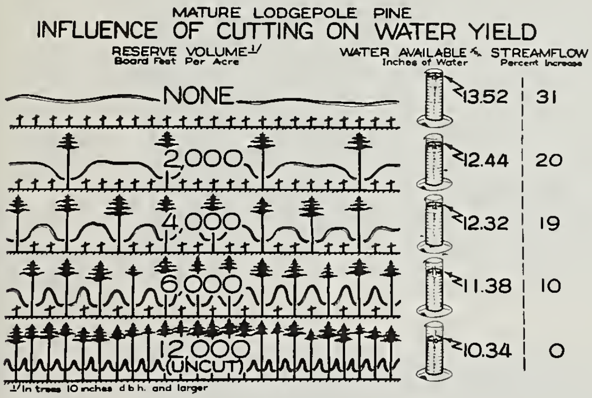
Twenty 5-acre plots were established in 1938 on the King Creek drainage in mature lodgepole pine. After snowpack, regeneration, and stand inventory measurements, plots were logged in 1940, with treatments ranging from clearcutting to no cutting. Residual volumes in trees 9.5 inches in diameter and larger on logged plots were 0, 2,000, 4,000, and 6,000 board feet (fbm) per acre. Uncut plots averaged about 12,000 fbm per acre.


INFLUENCE of THREE VEGETATIONAL TYPES ON WATER YIELD
SOURCE of WATER
LODGEPOLE PINE
QUAKING ASPEN
GRASSLAND
Inches of Water
WINTER SNOW STORAGE
8.4
10.9
9.6
SPRING PRECIPITATION
3.2
3.9
3.7
SUMMER PRECIPITATION
4.0
4.4
5.2


HEADQUARTERS
ST LOUIS CR
FOOL CR
N
LODGEPOLE PINE HARVEST CUTTING PLOTS
0
10
20 chains (1/4 mile)
ROAD
RESERVE STANDS
VIRGIN
6 M b.m. per acre
4 M b.m. " "
2 M b.m. " "
COMMERCIAL CLEAR CUT

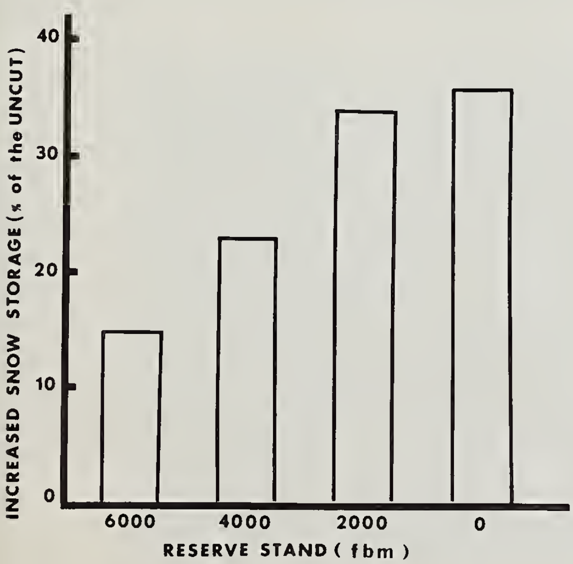
Water Available for Streamflow

Harvesting trees resulted in more water available for streamflow. The largest increase was on clearcut plots, the smallest was on 6,000 fbm reserve plots.



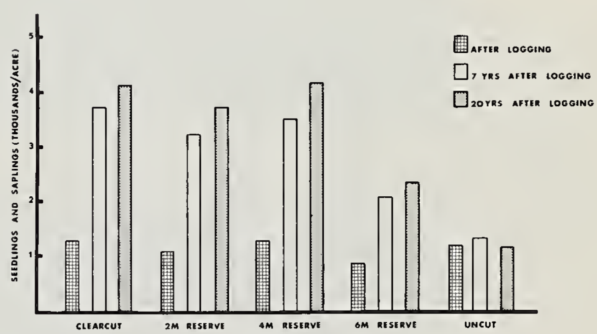
Snow Accumulation

Most of the increase in water available for streamflow came from increased snow storage on cutover plots. Although young trees developed rapidly on cutover plots, snow storage amounts have changed little in the years since cutting. This indicates the major cause of increased snow on cutover plots is the aerodynamic effect on snow distribution rather than reduced interception loss. Wind transports snow intercepted by trees in the surrounding uncut forest and deposits it in openings created by cutting trees. This pattern will persist until new trees, established after logging, are tall enough to change the aerodynamic effect on snow accumulation. To increase snow accumulation, clearcutting of mature lodgepole pine in small patches is the most desirable method of harvesting.



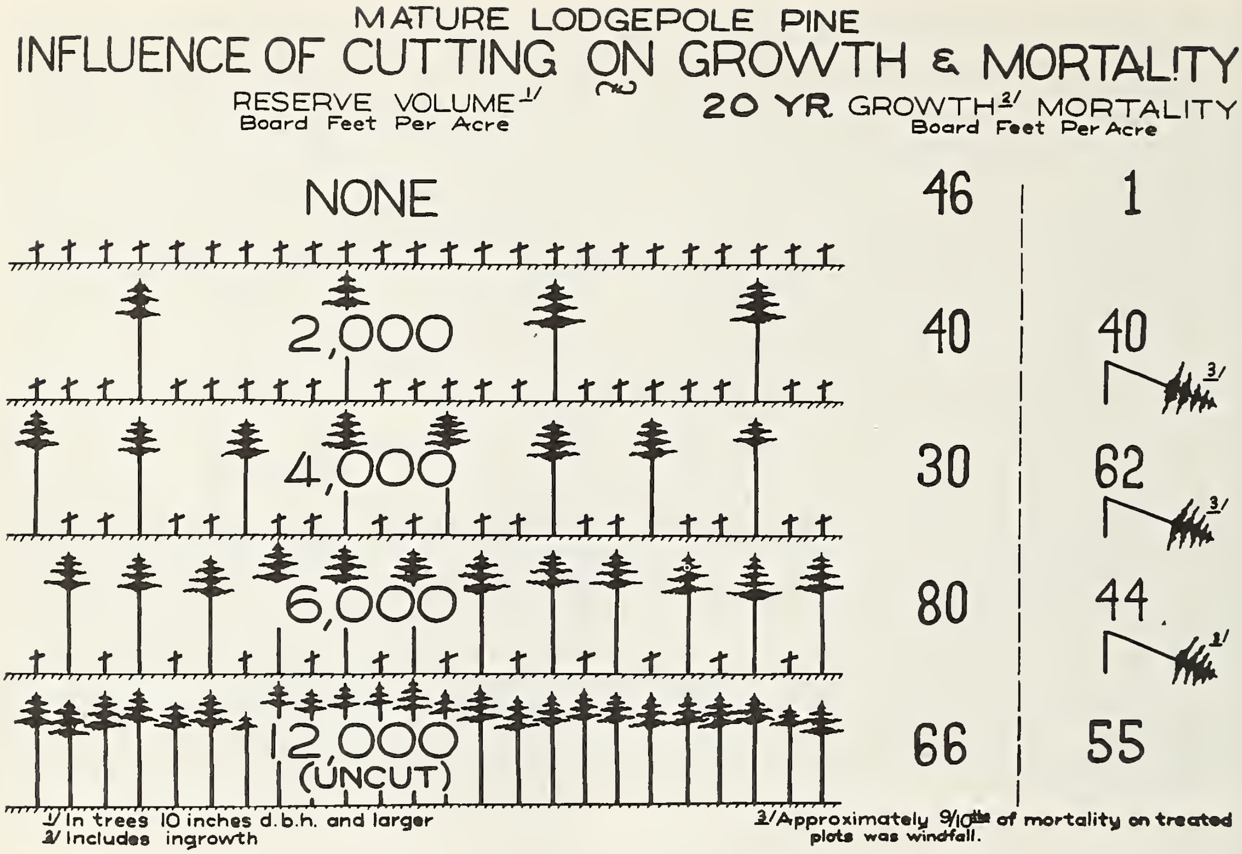
Regeneration

Enough new trees were established on all cutover plots. Before cutting, plots contained 1,978 seedlings and saplings per acre. Logging, where skidding was done with horses, destroyed 44% of the advanced growth, but new seedlings came in rapidly after logging. In only 7 years, new seedlings increased total reproduction twofold to threefold on all cutover plots. The increase was greatest on clearcut plots and least on 6,000 fbm reserve plots. Reproduction continued after 1947, but at a much slower rate, and the increase was not directly related to cutting method.



Growth and Mortality

Heavy mortality during the first 7 years after cutting resulted in little new growth on 6,000 fbm reserve and uncut plots, and an actual loss of volume on 2,000 and 4,000 fbm reserve plots. No measurable mortality occurred on clearcut



plots because no merchantable-sized trees were left. After 1947, mortality declined, and net growth increased on all plots. After 20 years, however, only the 6,000 fbm reserve plots grew more than uncut plots. Windfall was responsible for nearly all mortality on partially cut plots and about half the mortality on uncut plots. Because of heavy mortality, clearcutting and replacement of the old stand with a vigorous new one is recommended as the most desirable method for harvesting old-growth lodgepole pine. Partial cutting requires leaving large reserve volumes of low vigor trees, increasing the risk of future mortality.

Harvest Cutting Spruce-Fir

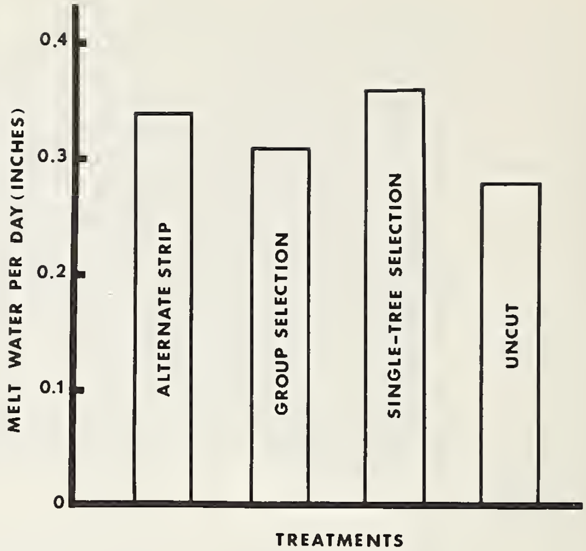
In 1944, four 8-acre plots were established on the West St. Louis Creek drainage to evaluate methods of cutting in old-growth spruce-fir forests. Treatments tested were alternate-strip clearcutting, group selection cutting and individual tree selection cutting. Each treatment removed 60% of the volume in trees 9.5 inches diameter at breast height (d.b.h.) and larger. Alternate-strip clearcutting removed 50% of the volume in alternate strips 1 chain wide; an additional 10% was removed from the leave strips by cutting overmature trees. Group selection cutting was used to remove 50% of the volume in small circular openings about 1 chain in diameter; an additional 10% was removed by cutting trees in the between-group stand. Individual tree selection cutting removed 60% of the volume uniformly over the entire plot. Residual volumes on cutover plots averaged 6,460 fbm per acre. The original volume of 17,745 fbm per acre remained on the uncut plot.

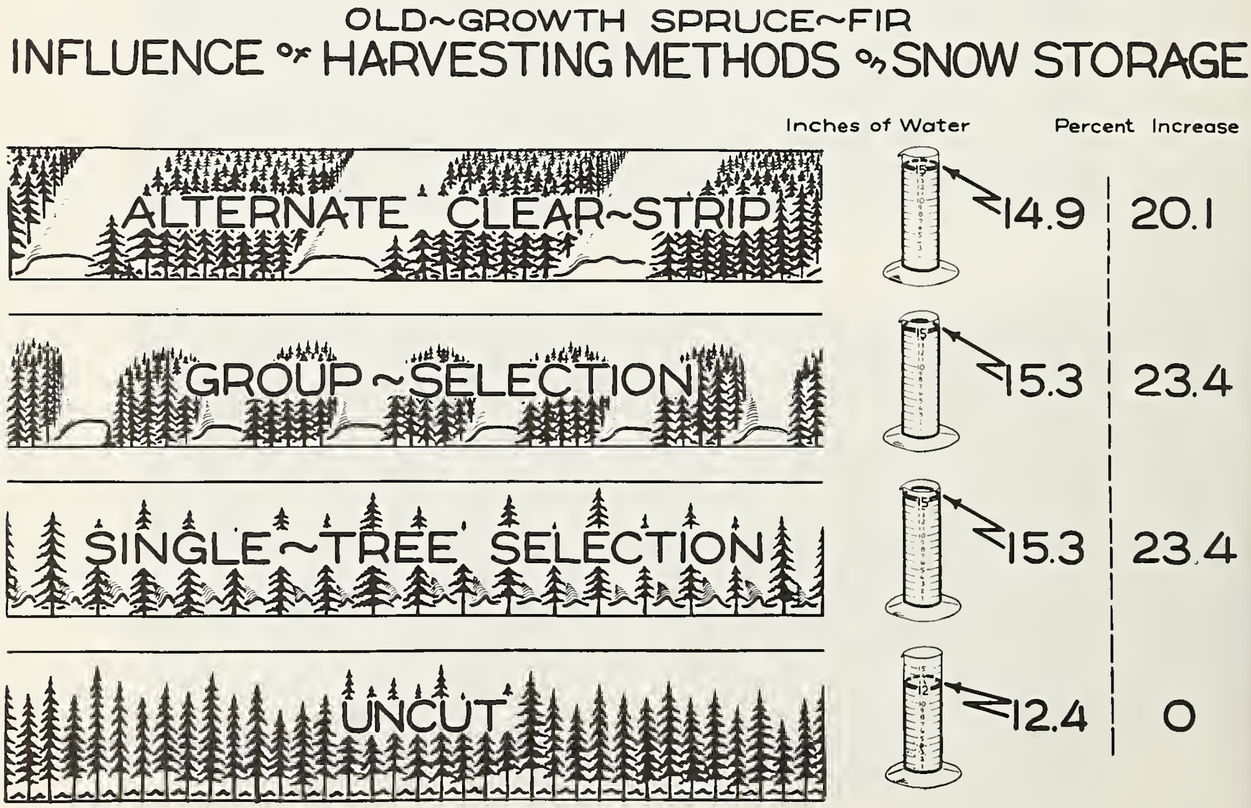
Snow Accumulation

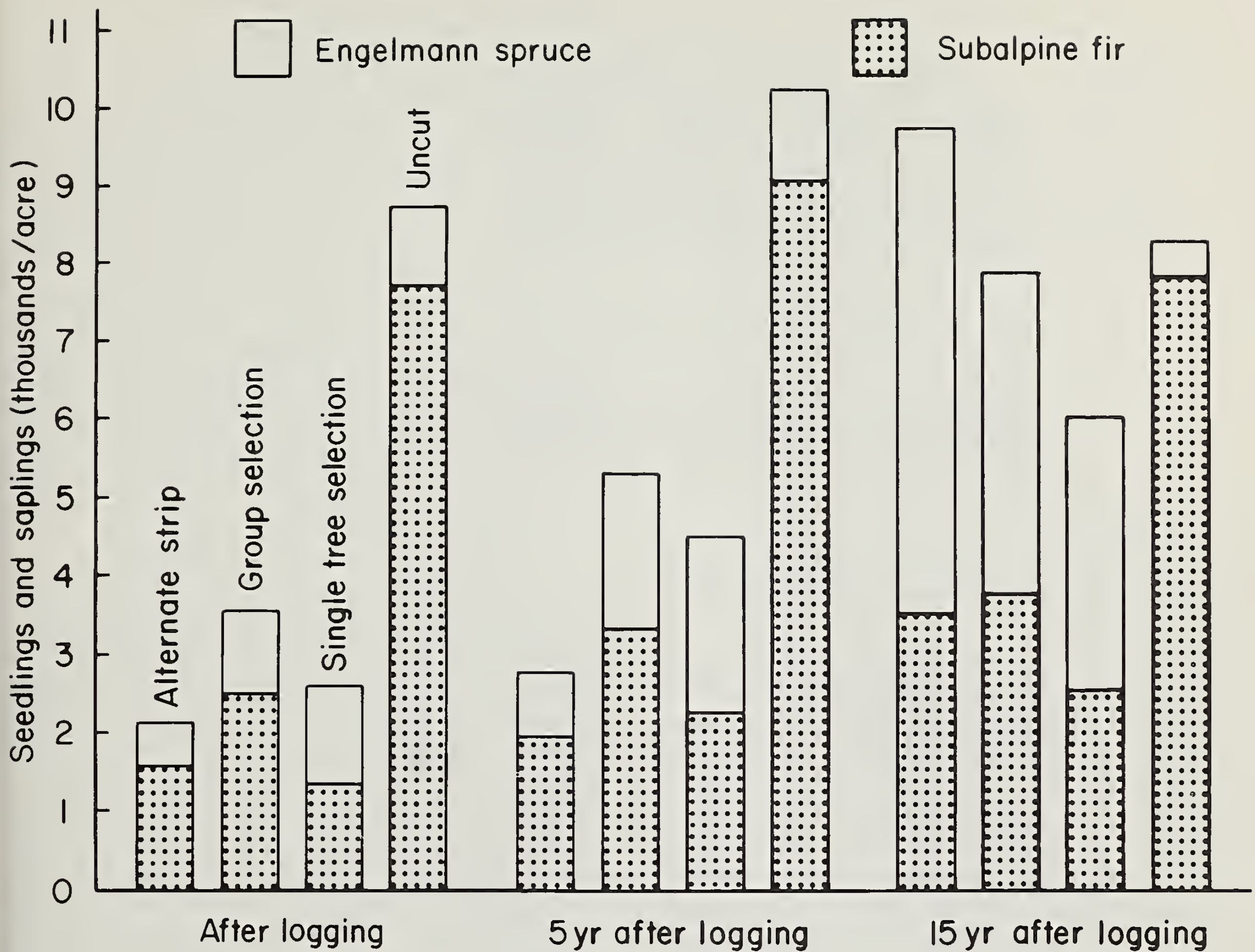
Snowfall reaching the ground increased on all cutover plots after logging. Measurements in four of the years after logging showed an average accumulation of 22% more water equivalent on cutover plots than on the uncut plot, but there were no differences in snow storage between treatments.

Snowmelt

Weekly measurements of rates of snowmelt during the spring showed only slight differences between treatments. Snow melted fastest (0.36 inch per day) after individual tree selection cutting and slowest (0.28 inch per day) in the uncut plot.





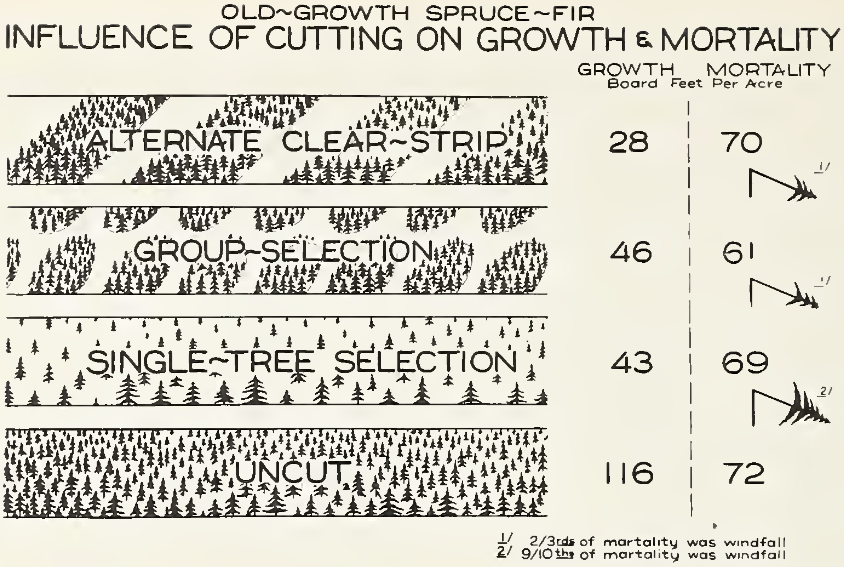


Regeneration

Reproduction was adequate under any cutting method tested. Before logging, plots averaged 6,344 seedlings and saplings per acre, with the ratio of fir to spruce ranging from 5 to 1 on the alternate strip clearcut plot to about 1 to 1 on the individual tree selection plot. Logging where skidding was with horses, destroyed 52% of the advanced reproduction. Damage among the three cut plots was heaviest on the individual tree selection plot where the entire area was disturbed, and was least on the group selection plot where about one-third of the area was disturbed. Subsequent reproduction established at only a moderate rate during the first 5 years after logging. Initial recovery was poorest on the alternate strip clearcut plot, where only about half as many trees established as on other cutover plots. The rate new reproduction established accelerated after 1949. The largest increase was on the alternate strip clearcut plot where new reproduction outnumbered the increase on group and individual tree selection cutting plots by three and four times, respectively. The number of new spruces was three to five times greater than new firs on all cutover plots.

Growth and Mortality

Growth of residual stands was not stimulated by the cutting methods tested. Furthermore, differences in board foot volume growth between

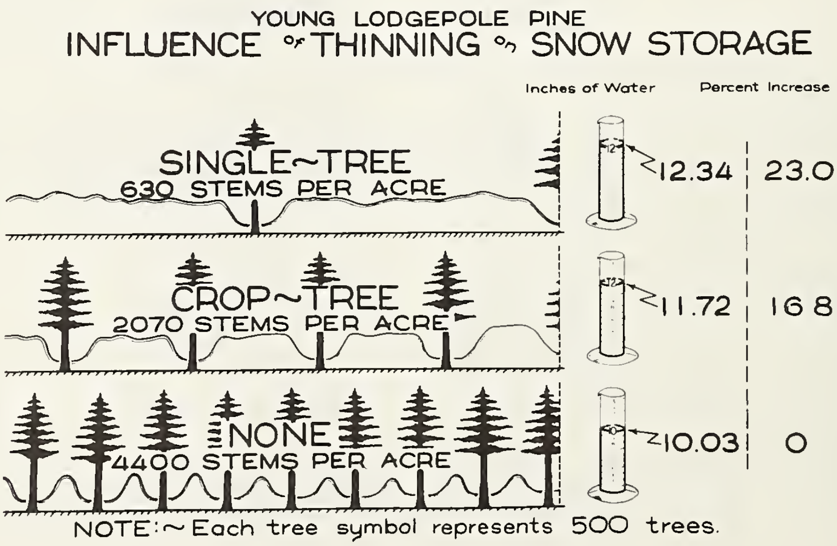


cutting treatments were unimportant. Mean annual growth on all plots was proportional to reserve volume.

Mortality was not materially different between plots. Windfall caused at least two-thirds of the mortality on cutover plots, with the heaviest losses on the individual tree selection plot. Disease and insects were responsible for most of the mortality on the uncut plot. Because of more abundant and better distributed spruce reproduction, and less susceptibility of residual stands to windthrow, alternate strip clearcutting and group selection cutting are the most desirable harvesting method tested for old-growth spruce-fir stands.

Thinning Young Lodgepole Pine

Eighteen ¼-acre plots were established in 1944 in young (35-year-old) lodgepole pine stands on St. Louis Creek to test thinning methods. Original stand density varied from 2,100 to 8,576 stems per acre. After snowpack and stand inventory measurements, six plots—designated single tree—were thinned uniformly from below in 1945, reserving 630 trees per acre. On six other plots — designated crop tree — all trees within a 16-foot diameter circle around each of 100 crop trees per acre were cut. The remaining six plots were left unthinned as a control.

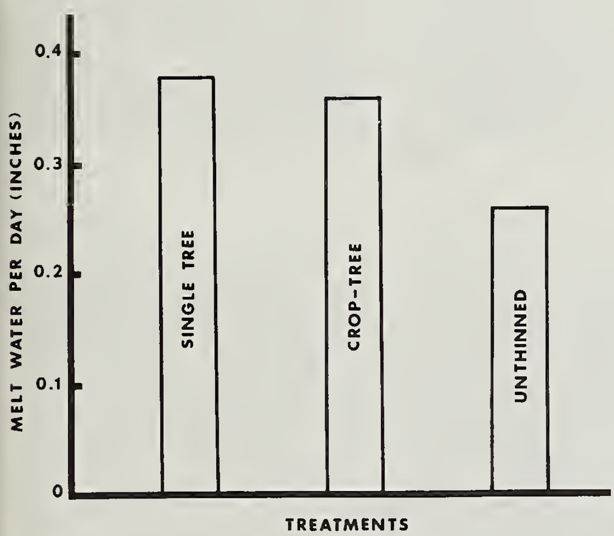


Snow Accumulation

Cutting resulted in more snow reaching the ground on thinned plots than in natural stands. The highest snow accumulation observed during a 3-year period was on single-tree plots where the largest number of trees were removed.

Snowmelt

The rate of snowmelt during spring was greater on thinned than unthinned plots, but there was little difference in melt between single-tree and crop-tree thinning.

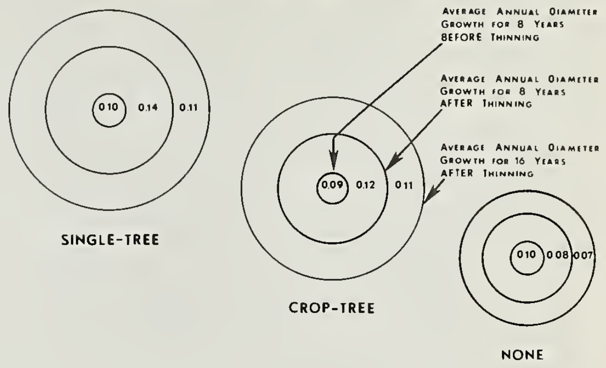


Growth

Diameter growth of the best 100 trees per acre was increased about 1½ times by both thinning methods during the 16 years of observation, but diameter growth of all trees on plots was increased only by single-tree thinning. Basal area increment of the total stand was not affected by thinning. Cubic volume growth during the first 8 years of observation was greater in unthinned than thinned stands, but during the last 8 years of observation, there was no difference in cubic volume growth between thinned and unthinned plots.

YOUNG LODGEPOLE PINE

INFLUENCE OF THINNING ON AVERAGE ANNUAL DIAMETER GROWTH OF SELECTED TREES



Because of larger increases in water available for streamflow and concentration of total stand growth on fewer stems, single-tree thinning is recommended.

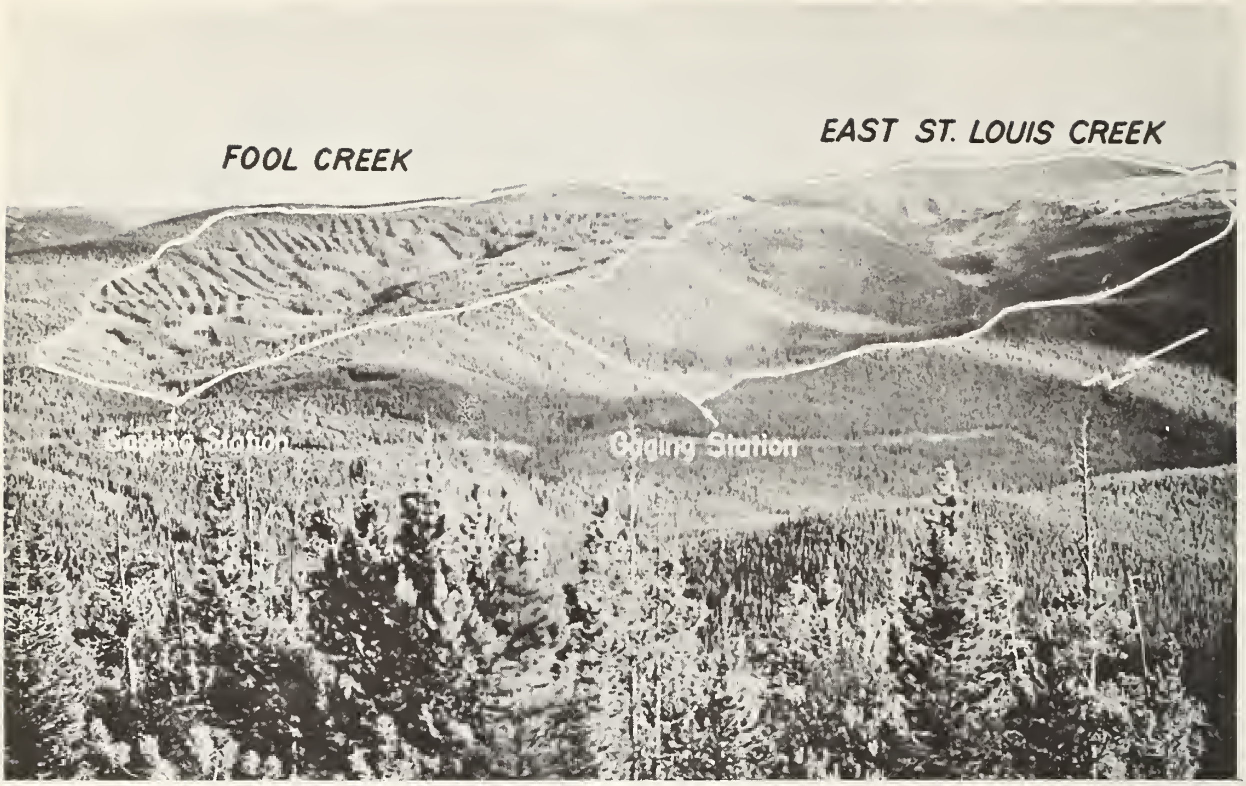
Watershed Studies—Fool Creek-East St. Louis Creek

Since more snow accumulated on experimental plots after timber harvest, it was assumed that more water was available for streamflow.[2] It was only an assumption, however, until similar cutting was done on a forested watershed where streamflow was measured.

Fool Creek.—This 714-acre watershed at elevations ranging from 9,500 to 11,500 feet, was selected for treatment. Streamflow, rainfall and snow storage have been measured since 1940. The gaging station at Fool Creek is a combination San Dimas flume and two broadcrested weirs. The main channel flows north, with generally east and west aspects comprising 70% of the watershed area.

East St. Louis Creek.—This is a 1,984-acre watershed with elevation varying from 9,500 to 12,200 feet. It lies adjacent to Fool Creek, and is

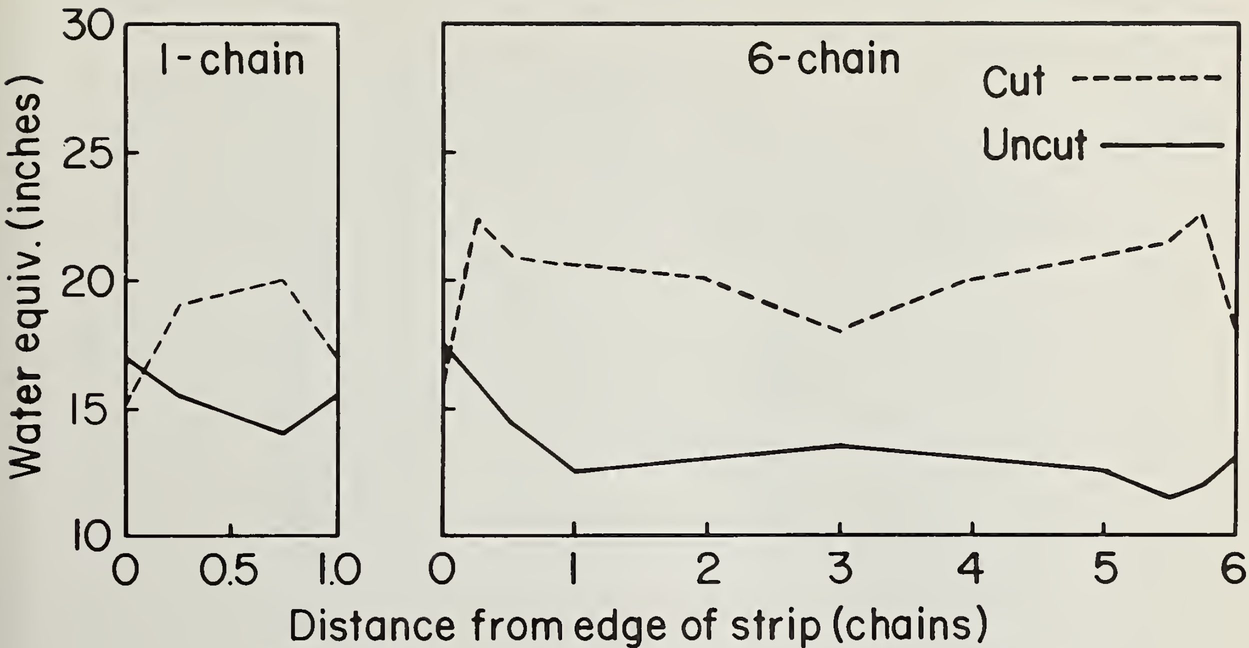
[2]Streamflow is the quantity of surface water flowing past a given point in a stream channel. It is measured by flumes, weirs, or water control structures. Streamflow generally is expressed as a rate in cubic feet per second, or as an amount in acre-feet, or inches depth over a known area.


FOOL CREEK
EAST ST. LOUIS CREEK
Gaging Station
Gaging Station

the untreated control. Major vegetation consists of lodgepole pine, Engelmann spruce and subalpine fir, with alpine tundra above timberline. Streamflow and snow storage have been measured since 1943. The original gaging station at East St. Louis Creek was a trapezoidal flume that was replaced in 1963 with a Cipolletti weir. Flow from the two watersheds correlates well, and changes in streamflow on Fool Creek resulting from timber harvest are estimated from the flow of East St. Louis Creek.

Alternate Strip Clearcutting

Fool Creek originally supported 6 million fbm of merchantable timber on 550 acres. About 55% was in the lodgepole pine type and 45 percent in the spruce-fir type. These stands were overmature, 250 to 350 years old. To harvest timber on Fool Creek, 3.3 miles of main access road and 8.8 miles of spur roads were constructed between 1950 and 1952. Spur roads were about 600 feet apart, located on the contour. Timber harvest, beginning in 1954 and ending in 1956, removed trees in alternate cleared strips at right angles to the contour. Four widths of clearing—1-, 2-, 3-, and 6-chains wide—were used. No timber was cut within 90 feet of the stream to minimize damage to the channel. On strips designated for cutting, all live trees 4 inches in diameter and larger were felled, and tops were lopped and scattered. In all, 278 acres of watershed were cleared, including 35 acres of roads. A total of 3.5 million fbm of timber was removed.

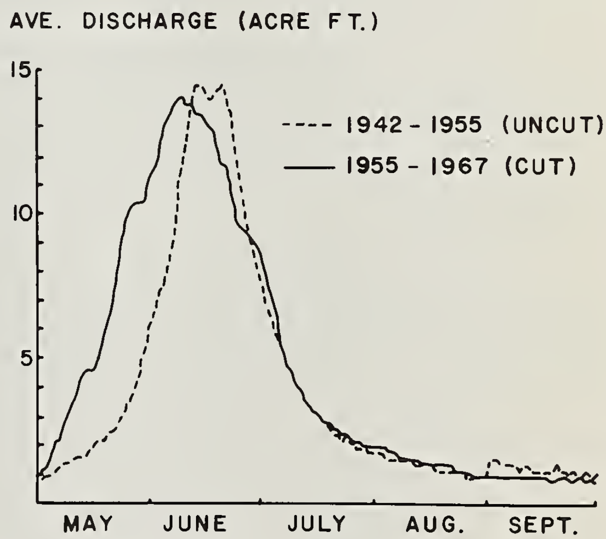


Snow Accumulation

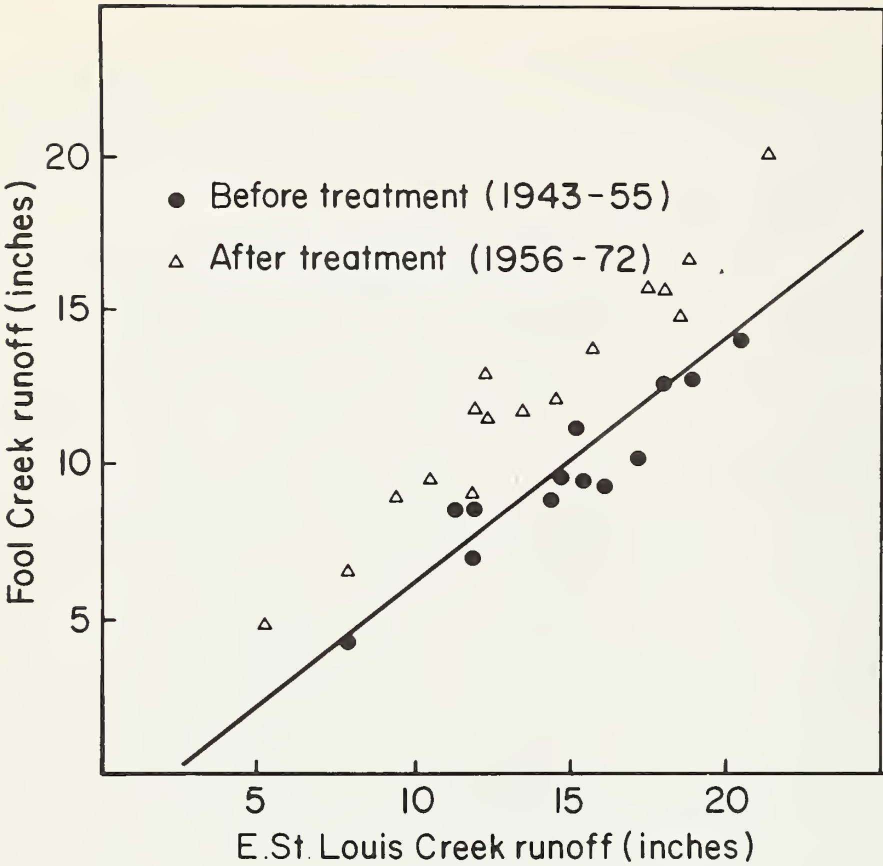
Comparisons of snowpack in alternate forested and clearcut strips show more water equivalent in open areas but no increase in total snow storage on the watershed. There is, however, a pronounced redistribution of snow as a result of cutting; more snow accumulates in cut strips than in the uncut forest. Before cutting, wind distributed snow rather evenly within the forest. Afterwards, openings increase wind stress on the remaining forest canopy and efficiently trap snow that formerly settled in adjacent forested strips.

Snowmelt and Water Yield

Removing timber from Fool Creek accelerated snowmelt rates and increased water yield by more than 25%. Most of the increase is due to a substantially enlarged spring runoff. Peak flows are not affected appreciably, and there is little change in streamflow during late summer and early fall despite higher snowmelt rates and more efficient water yield in early spring. More than 20 years have passed without any strong indication that the effect of cutting timber on streamflow has diminished.



Cutting trees and resultant redistribution of seasonal snowpack substantially increased runoff because some water formerly used to replace soil moisture consumed by vegetation is now available for streamflow, and more snow is deposited in openings where soil moisture deficits are lowest. Higher melt rates in openings further reduce water losses from evapotranspiration.



April - Sept.
Runoff Increase
Since Harvest

Year	Inches
1956	3.3
1957	5.2
1958	3.7
1959	4.6
1960	5.4
1961	3.4
1962	3.9
1963	2.9
1964	3.5
1965	4.0
1966	2.6
1967	3.1
1968	1.9
1969	2.5
1970	2.1
1971	3.6
1972	3.9
Mean	3.5 ±0.8*

*95 Percent level of confidence

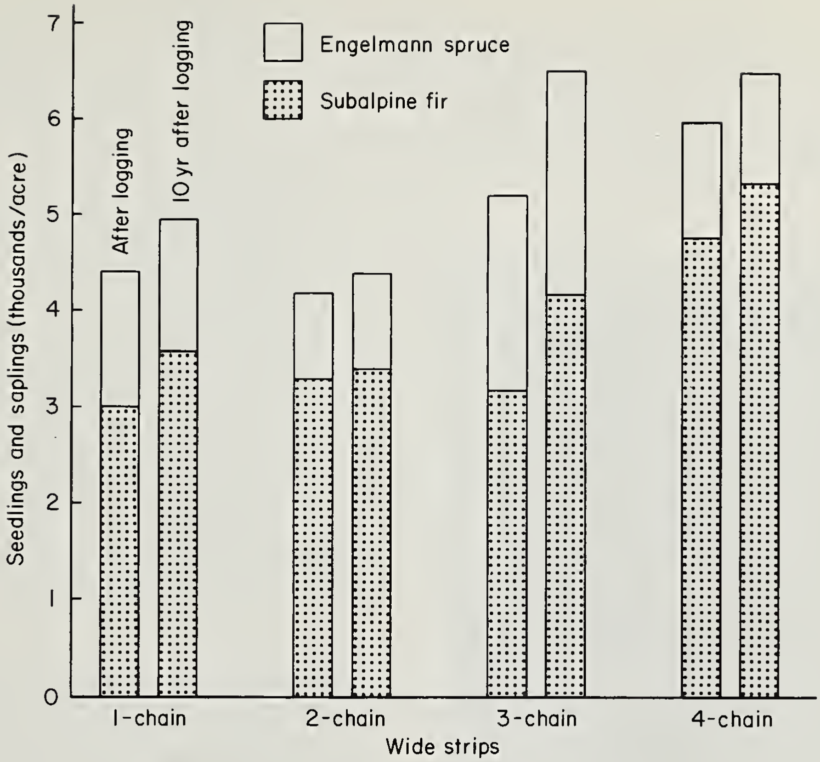
Sediment Yields

Construction of the road system on Fool Creek and associated timber harvesting caused little erosion, with no apparent reduction in water quality. The main access road was located to avoid damage to the stream channel, and spur roads were provided with surface drainage and culverts at stream crossings. After logging, spurs were seeded to grass, and culverts were removed from alternate spur roads to reduce traffic. The main haul road is still routinely maintained.

Sediment yield during road construction and logging averaged about 200 pounds per acre, but decreased rapidly after logging despite continuing increase in runoff after timber harvest. Since logging, sediment yields have averaged 43 pounds per acre, compared with yields of 11 to 21 pounds per acre from undisturbed watersheds. Suspended sediment was less than five parts per million during high flow periods in 1964 and 1965.

Regeneration: Spruce-Fir Type

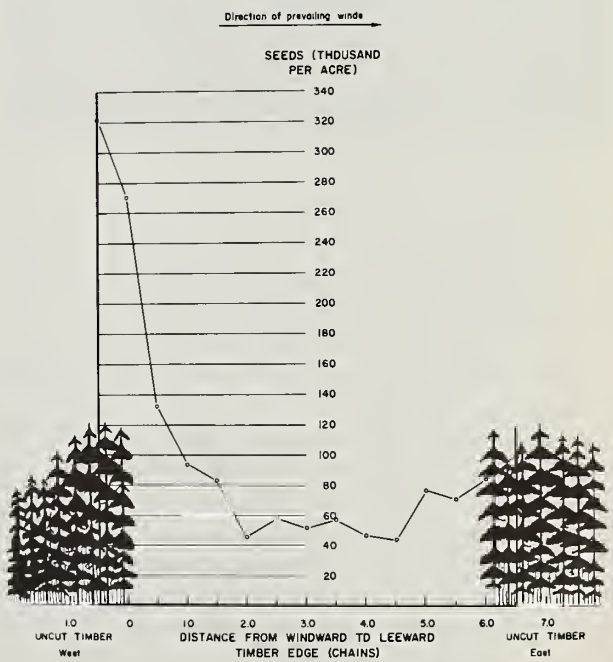
In the spruce-fir type on Fool Creek where logs were skidded with horses, enough advanced reproduction survived logging to restock all cutover strips. Numbers of seedlings and saplings



left after logging ranged from 4,183 per acre on 2-chain-wide strips to 5,957 per acre on 6-chain-wide strips. Firs outnumbered the more valuable spruces on all strip widths. Subsequent reproduction was not abundant on any strips 10 years after cutting. Recovery was best on 3-chain-wide strips, and poorest on 2-chain-wide strips. More new firs than spruces were established on all but 2-chain-wide strips.

Seed Dispersal: Engelmann Spruce

An adequate supply of viable seed is necessary for natural reproduction. During a 10-year period, 1956 through 1965, Engelmann spruce seed production in uncut strips on Fool Creek was 321,000 sound seeds per acre, but annual seedfall varied considerably. The 1961 crop contributed about 40 % of the total seedfall. Moderate crops were produced in 1959 and 1963, but seed crops were rated poor to complete failure in the other seven years of observation. Number of seeds dispersed from standing trees into the cleared strips was greater in years of heaviest seed production, but seedfall was not uniformly distributed over the openings. In the 6-chain-wide strips, about half the seed dispersed fell within 1.5 chains of timber edge, with only about 10% falling near the center of the openings.



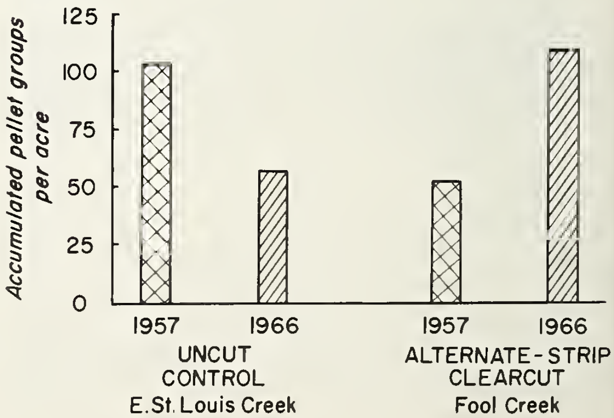
Windfall

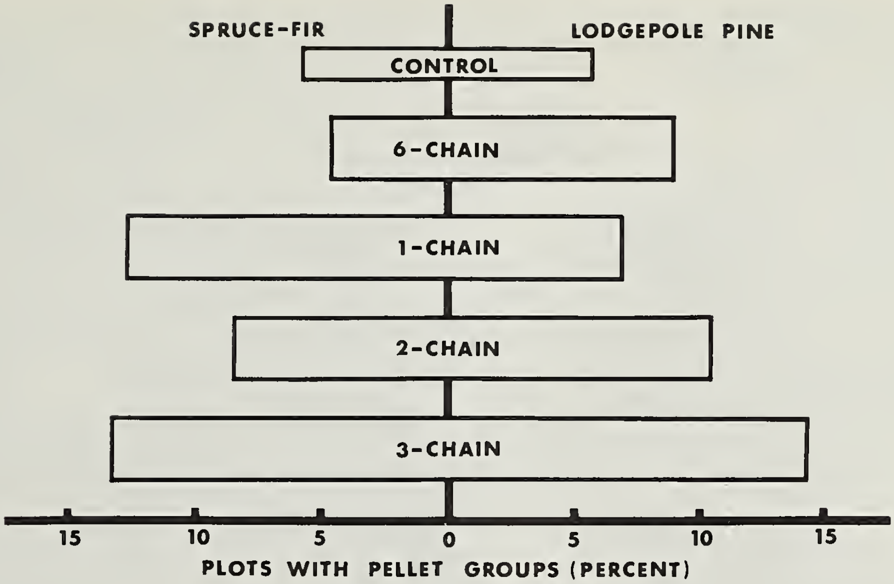
Windfall after clearcutting on Fool Creek was observed for 10 years after cutting was completed. Blowdown was related to exposure to wind, cutting unit characteristics, and tree characteristics in the following ways:

1. Approximately 70% of 2,844 windthrown trees were felled by stormwinds from the west and the southwest.
2. About two-thirds of the trees blew down along the N, NE, E, and SE (leeward) cutting boundaries.
3. More trees were windthrown on downwind than on upwind aspects.
4. Cutting boundaries on ridgetops suffered heavy damage. Fewer and about equal numbers of trees blew down on upper, middle and lower slopes.
5. Windfall was not directly related to width of opening.
6. Cutting boundaries oriented parallel to the direction of prevailing windstorms suffered more damage than those oriented at right angles to windstorms.
7. About two-thirds of the blowdown occurred within the first 2 years after logging.
8. Trees growing on soils where average depth of solum exceeded 12 inches were more windfirm than trees growing on shallower soils.
9. Trees growing in situations with rapid drainage were more windfirm than trees growing where drainage was slow.
10. All species and size classes were predisposed to windthrow in the same proportion in which they occurred in uncut stands.
11. Defect was associated with one third or less of windthrow trees.

Mule Deer Use and Forage Values

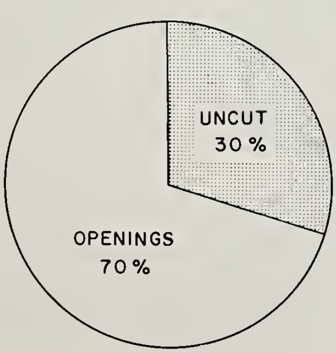
Immediately after logging, mule deer summer use on Fool Creek was less than on the adjacent unlogged watershed. Comparatively low use on Fool Creek may have been due to logging slash, and other disturbance associated with timber harvest. Ten years after logging, deer use was substantially higher on Fool Creek than on the control watershed, with most of the increase on cut strips. Comparisons among cut strips indicated 3-chain-wide strips were used most heavily on both spruce-fir and lodgepole pine forests. The 1-chain-wide strips were used least in lodgepole pine, while 6-chain-wide strips were used least in spruce-fir.





Tame mule deer observed in food habitat studies spent about 70% of their time and obtained about 70% of their food on cut strips. Since there were no differences between cut and uncut areas with respect to digestibility, crude protein content, or moisture content of forage species, deer preference for open areas was associated with increased amounts and variety of forage in cut strips. Although logging stimulated habitat changes beneficial to deer, enough forage was produced in unlogged areas to carry more deer than currently occupy the summer range. Deer populations in this area are limited by availability of winter range at elevations lower than on the Forest.

DEER USE OF OPENINGS AND UNCUT TIMBER



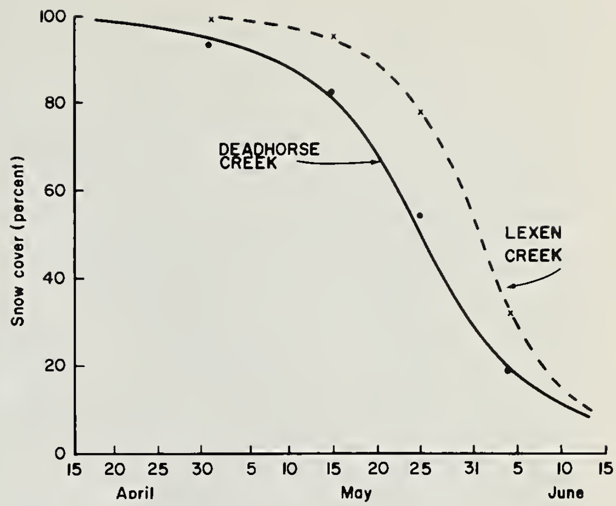
CURRENT RESEARCH

Watershed Studies: Deadhorse Creek—Lexen Creek

The hydrology of Deadhorse and Lexen Creeks has been studied since 1955. Long records of streamflow, snow accumulation and depletion, precipitation, sediment yield and water quality are available. A comprehensive study of the snowmelt regime on these and other watersheds on the Fraser Experimental Forest resulted in development of a simulation model capable of predicting short- and long-term hydrologic impacts of a broad range of land-use alternatives. The system represents the state of the art after more than 30 years of watershed management research in subalpine coniferous forests. Any tool of this complexity and scope requires pilot testing before routine operational application. Pilot testing will be accomplished on Deadhorse Creek by (1) simulating several timber harvesting options on various subunits, (2) selecting and applying one of these alternatives on the ground in each subunit, and comparing the runoff response predicted by the model with actual streamflow.

Deadhorse Creek.—This 667-acre watershed that generally drains from west to east, has been selected for treatment. Elevations vary from 9,450 feet at the main gaging station to 11,600 feet at the summit of Bottle Mountain. Major vegetation is spruce-fir along stream bottoms and all north and upper slopes, lodgepole pine on all lower and mid-south slopes, and alpine tundra above timberline. Deadhorse Creek is steeper than Fool Creek, with side slopes averaging almost 40%. The north and south exposures receive unequal amounts of heat in contrast to nearly equal radiant energy load on the east and west slopes of Fool Creek. The three stream gaging stations on Deadhorse Creek—on the main stream, on the 100-acre North Fork and on 200-acre Upper Basin—are 120° V-notch weirs. The main stream gage was constructed in 1955, the North Fork in 1970, and the Upper Basin in 1975.

Lexen Creek.—This is a 306-acre watershed at elevations ranging from 9,850 feet at the stream gaging station to 11,600 feet. It lies adjacent to Deadhorse Creek and will be the untreated control. Vegetation, soils, and topography are similar to Deadhorse Creek. The stream gaging station is a 120° V-notch weir constructed in 1955. Flows from the two watersheds are well-correlated, and Lexen Creek also can be used to estimate changes in streamflow on Deadhorse Creek caused by timber harvesting.



Pretreatment Hydrology

Snow Cover Depletion.—Aerial depletion of the snowpack on Deadhorse Creek starts earlier than on Lexen Creek because of advanced snowmelt on the low-elevation south slopes. The rate of depletion on the Upper Basin of Deadhorse Creek is similar to Lexen Creek.

Snowmelt.—Snowpack melt rates differ considerably between low elevation north and south slopes on Deadhorse Creek. Time of maximum snowmelt on the Upper Basin of Deadhorse Creek and on Lexen Creek varies considerably less between north and south slopes. As a result, nearly 90% of seasonal runoff volume is generated before 60% of the area is bare of snow in the Upper Basin of Deadhorse Creek and on Lexen Creek. Also, more than 80% of these areas are covered with snow when seasonal peak snowmelt runoff rates are reached.

Water Yields.—Streamflow from Lexen Creek can vary from 60% of Deadhorse Creek in high runoff years to nearly 90% in low runoff years because of differences in contribution to streamflow from the Upper Basin and lower Deadhorse Creek. The runoff above base flow on lower Deadhorse Creek averages less than 30% of that generated from the Upper Basin, even though precipitation at lower elevations is 80% of that at higher elevations. Low elevation water yields on Deadhorse Creek vary from near zero for poor runoff years to about 50% of the flow generated in the Upper Basin in good runoff years.

Sediment Yields.—Yields averaged 11 to 21 pounds per acre before road building and logging. These watersheds are very stable, characterized by coarse drainage structure and mature topography. Sediment yields are correlated with both peak and annual flows. In the undisturbed state, most total sediment load comes from stream bank erosion and channel degradation. Trapped elements range from well-graded gravel to fine sand.

YEAR	GENERATED RUNOFF[1]		RATIO OF RUNOFF,
	DEADHORSE CREEK	LEXEN CREEK	LEXEN:DEADHORSE
	- - - ACRE-FEET - - -		- - PERCENT - -
1956	647.8	397.0	61
1957	1,041.9	623.9	60
1958	688.8	424.6	62
1959	533.4	345.8	65
1960	595.2	384.0	64
1961	269.3	233.0	87
1962	943.9	580.0	61
1963	139.7	120.5	86
1964	339.5	275.4	82
1965	628.3	383.0	61
1966	213.3	186.7	88
1967	463.0	329.3	71
1968	439.1	328.9	75
1969	428.0	297.5	69
MEAN			70

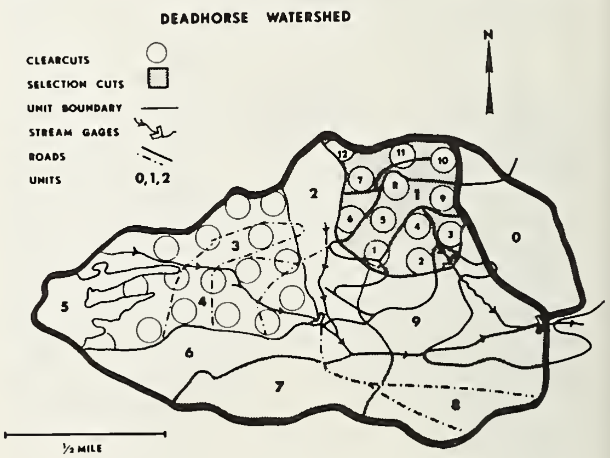
[1] ABOVE AN ASSUMED CONSTANT BASEFLOW OF 0.2 AND 0.1 CUBIC FOOT PER SECOND ON DEADHORSE AND LEXEN CREEKS, RESPECTIVELY.

Water Quality.—Natural flows from Deadhorse and Lexen Creek are generally pure. Concentrations of all chemical components are low, pH values near neutral, and temperatures very cold (0°-7°C).

Timber Harvest

Approximately 1 mile of main access road was built in 1955 to harvest timber and construct stream gaging stations on Deadhorse Creek. Another 2.5 miles of main access road was constructed in 1970-1971, and about 1 mile of main access road was built in 1976. Approximately 0.3 mile of main access road and 2.5 miles of spur road will be constructed in 1977. Additional roads needed will be built as timber harvesting proceeds.

North Fork (Response Unit 1).—A patch cutting operation has been selected for the North Fork of Deadhorse Creek. Long-term simulation of the hydrologic impacts of this option indicate an optimum water yield increase of 1.5 to 2.0 inches annually from this lower south slope subunit. This cutting pattern also is a first step to placing the timber stand under management.



Under this alternative, about 35% of the old-growth timber, principally lodgepole pine, will be removed by clearcutting small openings, about 400 feet in diameter, dispersed over the subunit. Present plans call for recutting these openings every 30 years to maintain increased water yield. No immediate cutting is proposed for the remaining timber stand.

The road system to remove timber from this subunit will be completed in early summer of 1977, with cutting to begin and finish in 1977 also. All live trees down to 4 inches d.b.h. on the cut patches will be removed. Logging will be done by conventional methods—downhill skidding of logs. Logging slash will be lopped and scattered. An estimated 200,000 fbm of timber will be removed.

North Slope (Response Unit 8).—A three-cut shelterwood option has been selected for this north slope subunit. Long-term simulation of the hydrologic impact of this option indicates no increase in runoff. This cutting pattern also will be a first step to placing the timber stand under management.

Under this alternative, about 40% of the old-growth, mixed lodgepole pine—spruce-fir stand will be removed on an individual tree basis throughout the subunit. An additional 30% of the old growth will be harvested in 20 years, with the remainder harvested in 40 years.

Roads to remove this timber will be constructed in 1977. The first cutting will begin and be completed in 1979. All cutting will be on an individual tree basis. Logging and slash disposal will be by conventional methods.

Upper Basin (Response Units 3 and 4).—A patch cutting alternative has also been selected for the Upper Basin of Deadhorse Creek. Long-term simulation of the hydrologic impacts of this option indicate an optimum water yield increase of 1.5 to 2.5 inches annually.

Under this alternative, 30 to 40% of the old-growth, mixed pine-spruce-fir timber will be removed by clearcutting small openings (five to eight times tree height in diameter) scattered over the subunit. This option differs from the North Fork in that initial openings will be regenerated and allowed to grow to maturity. New openings will be cut in 30 years, with the last of the old growth removed 60 years after the first cut.

The road system to remove timber from this subunit will be constructed in 1978. Cutting will begin and be completed in 1981. Trees removed and logging will be similar to that on the North Fork.

Operational Watershed Management

Operational aspects of watershed management—collecting and analyzing data on stream flow, snow accumulation and disappearance, water quality, sediment yield, soil water movement, temperature, precipitation, and radiation—will continue on Deadhorse and Lexen Creeks. These data are needed to determine treatment responses and provide input to test the hydrologic simulation model.

Game Animals

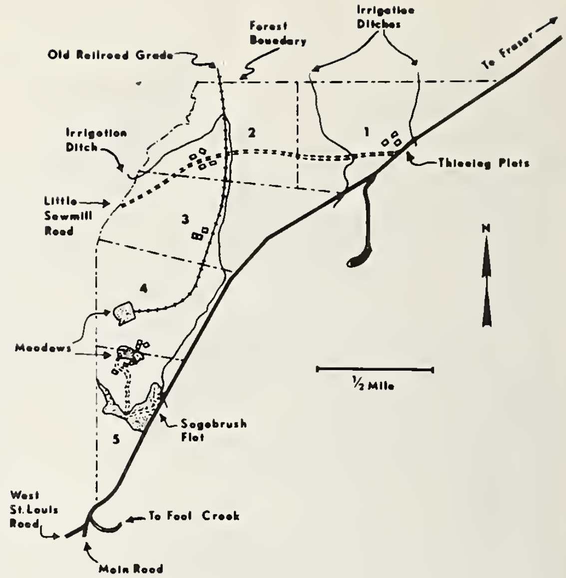
On all subunits scheduled for timber harvesting, use by mule deer, elk, and blue grouse is being sampled to determine impact of cutting timber on animal population density and distribution. Cover and composition of understory vegetation and biomass also is being sampled to determine response to timber harvesting options.

Nongame Birds and Small Mammals

Species and population densities of small mammals and nongame birds on subunits scheduled for timber harvest also are being inventoried to determine their responses to changes in habitat resulting from treatment. These data will provide information on habitat requirements of small mammals and birds that inhabit subalpine coniferous forests.

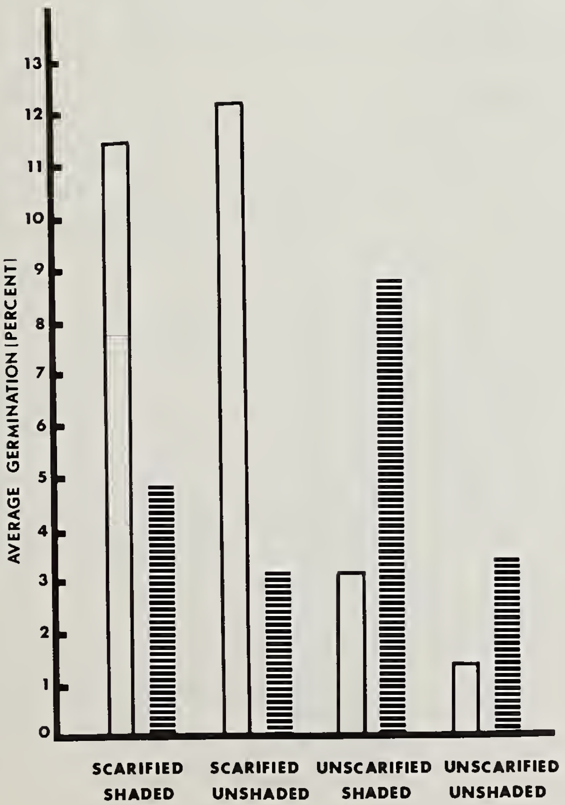
Levels of Growing Stock—Young Lodgepole Pine

In 1975, a study was started in second-growth lodgepole pine stands on St. Louis Creek drainage to test different thinning levels. The study area was divided into five units, with one unit scheduled for thinning each year for 5 years. Within each unit, three 0.4-acre plots will be thinned from below, each to a different growing stock level (80, 100, 120). The first series of plots, in Unit 1, were thinned in 1976. The last series of plots, in Unit 5, will be thinned in 1981. Periodic remeasurement will provide information on stand growth at different stocking levels, rate of spread and intensification of dwarf mistletoe infection, population density and distribution of deer and elk in relation to overstory density, relative herbage production in relation to basal area of residual overstory, forage availability to animals, soil moisture withdrawal in relation to overstory density and depth below the soil surface, and seasonal progress of soil moisture depletion.



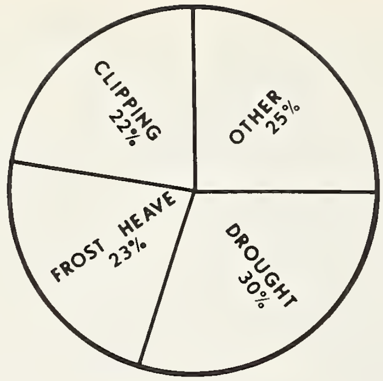
Environmental Factors Affecting Engelmann Spruce Regeneration

Two study areas were established in 1967 and 1968 to identify factors limiting spruce regeneration success, and determine cultural practices needed to provide an environment suitable for spruce regeneration. Study plots are located in two 3.5-acre clearcut openings at 10,500 feet elevation, one on a north slope of the Fool Creek drainage, the other on a south slope of the West St. Louis Creek drainage.

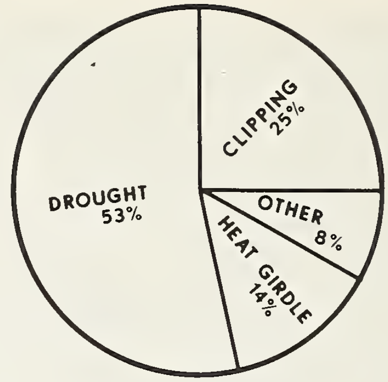


AVERAGE GERMINATION (PERCENT)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
NORTH SLOPE
SOUTH SLOPE
SCARIFIED SHADED
SCARIFIED UNSHADED
UNSCARIFIED SHADED
UNSCARIFIED UNSHADED

AVERAGE SURVIVAL (PERCENT)
0
1
2
3
4
5
6
SCARIFIED SHADED
SCARIFIED UNSHADED
UNSCARIFIED SHADED
UNSCARIFIED UNSHADED



NORTH SLOPE



SOUTH SLOPE

Each year, twelve 4 x 12 m seedbeds are prepared at each study site. Each set is composed of four seedbed treatments—scarified-shaded, scarified-unshaded, unscarified-shaded, and unscarified-unshaded—replicated three times each. Seed is sown each fall on the current set of seedbeds to simulate natural seedfall.

Five years of observation indicates that germination on the north slope is best on scarified-unshaded seedbeds and poorest on unscarified-unshaded seedbeds; survival is best on scarified-shaded seedbeds and poorest on unscarified-unshaded seedbeds. Nearly 80% of the germinating seedlings died, with most mortality caused by drought, frost heaving, and clipping by birds. Four years of observation indicates germination on south slopes is best on unscarified-shaded seedbeds and poorest on scarified-unshaded seedbeds; survival is best on unscarified seedbeds and poorest on scarified-unshaded seedbeds. About 90% of the germinating seedlings died, with most mortality caused by drought, clipping by birds, and heat girdle.

The most favorable and unfavorable conditions for Engelmann spruce regeneration success are summarized in the table below.

REGENERATION CONDITIONS

FAVORABLE		UNFAVORABLE
>600,000 SEED/HA	-SEED CROP-	<60,000 SEED/HA
NORTH	-ASPECT-	SOUTH
AMBIENT AIR >0°C NIGHT AND <25°C DAY; MAXIMUM SURFACE <30°C	-TEMPERATURES-	AMBIENT AIR <0°C NIGHT AND >25°C DAY; MAXIMUM SURFACE >30°C
>1.0 CM/WEEK	-PRECIPITATION-	<1.0 CM/WEEK
LIGHT-TEXTURED, SANDY-LOAM	-SOIL-	HEAVY-TEXTURED, CLAY-LOAM
50 PERCENT EXPOSED MINERAL SOIL	-SEEDBED-	10 PERCENT OR LESS EXPOSED MINERAL SOIL
40-60 PERCENT DEAD SHADE		10 PERCENT OR LESS DEAD SHADE
DUFF AND LITTER <5 CM		DUFF AND LITTER >5 CM
LIGHT VEGETATIVE COVER		HEAVY VEGETATIVE COVER
SEEDLINGS >12 WEEKS OLD BY MID-SEPT.	-SURVIVAL-	SEEDLINGS <12 WEEKS OLD BY MID-SEPT.
LOW POPULATION OF BIRDS AND RODENTS THAT EAT SEEDS AND SEEDLINGS		HIGH POPULATION OF BIRDS AND RODENTS THAT EAT SEEDS AND SEEDLINGS
PROTECTION FROM TRAMPLING		NO PROTECTION FROM TRAMPLING
SNOW COVER WHEN FROST-HEAVING CONDITIONS EXIST		NO SNOW COVER WHEN FROST-HEAVING CONDITIONS EXIST

Engelmann Spruce Seed Production

A long term study of Engelmann spruce seed production was started in 1968 on the Forest. By 1970, thirteen 0.4-acre plots were established at different elevations, aspects, etc. Good to heavy crops were produced during four of the first five years of observation, with some locations occasionally producing bumper crops. Much more seedfall data are needed to predict frequency of good seed crops and to identify the kinds of stands likely to provide good seed crops.

SIDELIGHTS

Facilities of the Fraser Experimental Forest are used occasionally for school training, undergraduate field work, field meetings of forestry and conservation societies, and Foreign Agriculture Service programs in forestry. Excellent examples nearby serve as on-the-ground illustrations of both beneficial and harmful practices in mountain agriculture.

Opportunities for graduate students to undertake fundamental research in conservation and use of natural resources are excellent. Arrangements may be made on a cooperative basis with the U.S. Forest Service through colleges, universities, foundations, or other interested groups.

Visitors are always welcome. To obtain more detailed published information about the experimental work, ask the resident scientists or send a request to Director, Rocky Mountain Forest and Range Experiment Station, 240 West Pròspect, Fort Collins, Colo. 80521.

APPENDIX A

Species List of Birds

Common Name	Scientific Name
MIGRATORY BIRDS	
Mallard	*Anas platyrhynchos*
Teal	*Anas* spp.
Golden eagle	*Aquila chrysaetos*
American kestrel	*Falco sparverius*
Spotted sandpiper	*Actitis macularia*
Mourning dove	*Zenaida macroura*
Rufous hummingbird	*Selasphorus rufus*
Black-billed magpie	*Pica pica*
Clark's nutcracker	*Nucifraga columbiana*
Black-capped chickadee	*Parus atricapillus*
Mountain bluebird	*Sialia currucoides*
Red-winged blackbird	*Agelaius phoeniceus*

SEASONAL NESTING BIRDS	
Goshawk	*Accipiter gentilis*
Sharp-skinned hawk	*Accipiter striatus*
Marsh hawk	*Circus cyaneus*
Red-tailed hawk	*Buteo jamaicensis*
Screech owl	*Otus asio*
Great horned owl	*Bubo virginianus*
Common nighthawk	*Chordeiles minor*
Broad-tailed hummingbird	*Selasphorus platycercus*
Common flicker	*Colaptes auratus*
Yellow-bellied sapsucker	*Sphyrapicus varius*
Williamson's sapsucker	*Sphyrapicus thyroideus*
Hammond's flycatcher	*Empidonax hammondii*

Western flycatcher	*Empidonax difficilis*
Western wood pewee	*Contopus sordidulus*
Olive-sided flycatcher	*Nuttallornis borealis*
Horned lark	*Eremophilia alpestris*
Steller's jay	*Cyanocitta stelleri*
Common crow	*Corvus brachyrhynchos*
Dipper	*Cinclus mexicanus*
Red-breasted nuthatch	*Sitta canadensis*
Brown creeper	*Certhia familiaris*
American robin	*Turdus migratorius*
Townsend's solitaire	*Myadestes townsendi*
Hermit thrush	*Catharus guttatus*
Gold-crowned kinglet	*Regulus satrapa*
Ruby-crowned kinglet	*Regulus calendula*
Yellow-rumped warbler	*Dendroica coronata*
Wilson's warbler	*Wilsonia pusilla*
House finch	*Carpodacus mexicanus*
Pine grosbeak	*Pinicola enucleator*
Pine siskin	*Carduelis pinus*
Red crossbill	*Loxia curvirostra*
Gray-headed junco	*Junco caniceps*
White-crowned sparrow	*Zonotrichia leucophrys*

YEARLY RESIDENT BIRDS

Blue grouse	*Dendragapus obscurus*
White-tailed ptarmigan	*Lagopus leucurus*
Hairy woodpecker	*Picoides villosus*
Downy woodpecker	*Picoides pubescens*
Northern three-toed woodpecker	*Picoides tridactylus*
Gray jay	*Perisoreus canadensis*
Common raven	*Corvus corax*
Mountain chickadee	*Parus gambeli*

APPENDIX B
Species List of Mammals

Common Name	**Scientific Name**
Vagrant shrew	*Sorex vagrans*
Northern watershrew	*Sorex palustris*
Masked shrew	*Sorex cinereus*
Little brown myotis (bat)	*Myotis lucifugus*
Black bear	*Ursus americanus*
Marten	*Martes americana*
Longtail weasel	*Mustela frenata*
Shorttail weasel (rare)	*Mustela erminea*
Mink (rare)	*Mustela vison*
Striped skunk	*Mephitis mephitis*
Badger (occasional)	*Taxidea taxus*
Red fox	*Vulpes fulva*
Coyote	*Canis latrans*
Mountain Lion (rare)	*Felis concolor*
Bobcat	*Lynx rufus*
Yellowbelly marmot	*Marmota flaviventris*
Golden mantled squirrel	*Citellus lateralis*
Least chipmunk	*Eutamias minimus*
Colorado chipmunk (questionable)	*Eutamias quadrivittatus*
Uinta chipmunk	*Eutamias umbrinus*
Spruce squirrel	*Tamiasciurus fremonti*
Northern pocket gopher	*Thomomys talpoides*
Deer mouse	*Peromyscus maniculatus*
Bushytail woodrat	*Neotoma cinerea*
Mountain phenacomys (Heather vole)	*Phenacomys intermedius*
Boreal redback vole	*Clethrionomys gapperi*
Montane vole	*Microtus montanus*
Long-tailed vole	*Microtus longicaudus*
Western jumping mouse	*Zapus princeps*
Muskrat	*Ondatra zibethica*
Beaver	*Castor canadensis*
Porcupine	*Erethizon dorsatum*
Pika	*Ochotona princeps*
Snowshoe hare	*Lepus americanus*
Elk	*Cervus canadensis*
Mule deer	*Odocoileus hemionus*

Alexander, Robert R. and Ross K. Watkins. 1977. The Fraser Experimental Forest, Colorado. USDA For. Serv. Gen. Tech. Rep. RM-40, 32 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

This report provides a general overview of work done on the Fraser Experimental Forest. It replaces Station Paper No. 8, published in 1952 and revised by L. D. Love in 1960. Included are descriptions of physical features and resource values, and highlights of past and current research programs.

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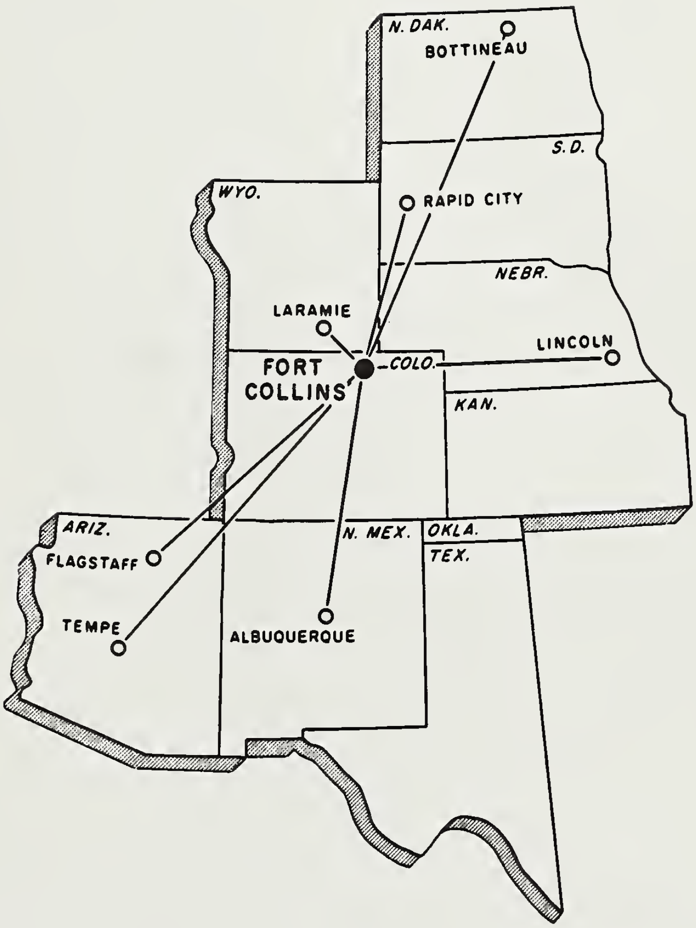
N. DAK.
BOTTINEAU
S.D.
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The Fraser Experimental Forest is a research unit of the Rocky Mountain Forest and Range Experiment Station, which is maintained in cooperation with the Colorado State University at Fort Collins, Colorado